Situated and overview data in the shared spaces of community gardens

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I, **Geraint Rhys Sethu-Jones**, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

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Abstract

Urban spaces are increasingly being used to grow plants (Hirsch et al., 2010) by communities (Blevis and Morse, 2009). Gardening is a complex task (Lyle, 2013) that could benefit from technological support (Campbell, 2013) (Lyle, 2013), however existing sensing and data technologies do not transfer well to a community context (Campbell, 2013) despite demonstrated benefits in commercial and industrial settings (Seelan et al., 2003). Some have argued that such technologies are inherently unsuitable for community growing contexts (Odom, 2010), however it is the specific *design* of these technologies that is inappropriate to a 'natural world' context, rather than technology itself (Bidwell and Browning, 2010).

This thesis seeks to explore the tension between the potential benefits of sensors and data in community gardens, and the non-use of these technologies, using a Research In The Wild (RITW) approach (Rogers and Marshall, 2017).

Contextual interviews were conducted in 5 community gardens to establish context and practice. This was followed by a design workshop, to elicit responses to novel technologies. The third phase was an experiment investigating theoretical questions about space and data that arose from the earlier phases. The fourth phase involved deploying a provocative prototype into a community garden, to investigate responses to novel technology in context.

There are three contributions of this thesis based on this exploration of community gardens as shared spaces. The primary contributions are;

1. **Domain Specific** key themes and implications for design, and

2. **Empirical** observations about how situated and overview data representations alter the emergence of action in shared spaces.

Additionally, there is a secondary reflective **Methodological** contribution, focusing on the use of RITW as a framing for research.

Impact

The work presented in this thesis and its contributions has impact both inside and outside academia, and the findings have been published and presented at HCI conferences.

Within academia, there are three main areas of impact. Firstly, we have demonstrated that sensors and data in community gardens is an area of potential interest to HCI researchers, and that 'technological rejection' is not inherent to this domain. We present design principles and possible directions for further research into systems which may be adopted and adapted by community gardeners. Secondly, we present findings that suggest locality of data representations in shared spaces may affect the emergence of action in these spaces. Exploring the different aspects of locality, and effects and applicability across other contexts provides a rich vein of potential further research. Thirdly, this thesis helps to develop methods in the field by reflecting on the use and adaptation of RITW as a guiding framework.

These three contributions are applicable beyond academia; The presented design principles could be used directly by designers or communities in the domain of interest, or in shared spaces more broadly. Locality can be used as conceptual tool for the design of systems intended to be used in shared spaces, or as a way to analyse and characterise existing systems. Finally, the reflections on and extensions to the RITW framework as a guiding method could be used as a case study for the application of RITW as a method in User Experience research and design, particularly for novel technologies intended to be used in shared spaces.

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Publications

Some aspects of the work reported in this thesis have previously been published:

Conference papers

1. Sethu-Jones, G. R., Y. Rogers, and N. Marquardt (2017). "Data in the garden: a framework for exploring provocative prototypes as part of research in the wild". In: *Proceedings of the 29th Australian Conference on Computer-Human Interaction.(OZCHI'17)* ACM, pp. 318–327.

Workshop papers

2. Jones, G. R., Y. Rogers, and N. Marquardt (2016). "Presence and Use: Sensors In Community Gardening". In: *CHI'2016 NatureCHI Workshop.* ACM.
3. Jones, G. R., Y. Rogers, and N. Marquardt (2015). "Tiny Data: Situated Data Analysis to Support Community Decision Making". In: *CHI'2015 Alternative Systems Workshop.* ACM.

Publication 1 reports on the provocative prototype study in chapter 7, and some of the material discussed in chapter 8. Publication 2 touches on overarching themes across the studies presented in chapters 4,5, and 7, and Publication 3 reports on the contextual study in chapter 4.

Contents

1 Introduction

There is a tension in community gardening (Sethu-Jones, Rogers, and Marquardt, 2017): the non-use of sensing technology in community practice (Hirsch, 2014; Odom, 2010), despite potential benefits to community gardening (Campbell, 2013) and the use and demonstrated benefits of such technology in industrial and consumer settings (Seelan et al., 2003). This PhD thesis aims to investigate and address this tension by examining sensors and data in community gardens, using a mix of research methodologies within a Research In The Wild framework (Rogers and Marshall, 2017).

1.1 Sensors and data in community gardening

Community food growing has recently been emerging as an area of interest for HCI (Odom, 2014), as has sustainable HCI more generally (Choi and Blevis, 2010). Urban and periurban dwellers are increasingly reclaiming spaces to grow plants in cities and suburbs (Hirsch et al., 2010). Elst and Richards-Rissetto (2013) argue that this is driven by ideological desires for environmentally sustainable, local and healthy food, however gardeners are also motivated by a need to interact more closely with nature (Odom, 2010). Despite growing engagement in the area from designers and technologists, there had previously been little interest amongst HCI researchers (Hirsch, 2014), and there is a dearth of work in the literature specific to the design of interactive systems for this context of small-scale, community gardening Odom (2014).

Gardens are complex environments made up of webs of interdependent systems, and successful gardeners must draw not only on specialist domain knowledge but also on an understanding of the local environment in order to reliably grow plants (Lyle, 2013). Success is particularly important for community gardens, as if community gardens do not demonstrate viability, participants become disengaged and loose interest (Bunch and

Scarborough, 1998). There are a number of sensing technologies that could help gardeners to gain a deeper understanding of these local environmental conditions (Campbell, 2013), however despite being used successfully in a variety of commercial settings such as farms (Seelan et al., 2003) and vineyards (Burrell, Brooke, and Beckwith, 2004), these techniques have not been widely adopted by community gardeners (Campbell, 2013; Odom, 2010). It has been argued that community gardeners are rejective of technology because they think it will interfere with their relationship with the garden (Odom, 2010; Goodman and Rosner, 2011), and some have concluded that sensors and data in the garden are not appropriate or beneficial for community gardening groups (Hirsch, 2014; Odom, 2010). However, Bidwell and Browning (2010) argue that it is not that technology itself is inherently inappropriate for a natural world context, but rather that it is the *specific design* of many technologies that makes them unsuitable for such contexts.

Current commercial and industrial solutions follow the prevailing design ethos of one person, one device, and one app at a time (Klokmose and Zander, 2010), a paradigm that does not support collocated interactions (Lundgren et al., 2015) but rather seeks to provide 'artificial proximity' for remote interactions (Mejia, Morán, and Favela, 2007). Robinson, Marsden, and M. Jones (2014) argue that this 'digital primacy' doesn't just distract people from the 'real world', but by providing a compelling alternate reality within the device it leads to a disconnection with the real world, which is particularly damaging to the experience of being within a natural context (Bidwell and Browning, 2010). Goodman and Rosner (2011) argue that it is this disconnect from experiencing the garden that makes gardeners wary of adopting 'technology' into their practice.

Given that current technologies are not adopted into current practice, how can we design sensor and data systems that support usage in these complex shared spaces, that address this tension of non-use versus potential benefit, and encourage use and appropriation by community gardeners?

In order to reconcile this tension, it is important not only to understand the existing context and practice of community gardeners and their response to existing technology, but also to investigate how sensing technologies could alter and contribute to future practices in community gardening. As such, this context lends itself to a Research In The Wild (Rogers and Marshall, 2017) project where we can approach the problem on two fronts:

1. **Context and practice**

   How does practice currently emerge in community gardens?

2. **Technological provocation**

   How can sensor and data technology benefit future practice?

By exploring potential future practices in this way, we can explore beyond rejections of current designs with what Furniss et al. (2015) call *non-incremental design considerations*.

1.2 Definitions

Community Gardens are defined for the purposes of this thesis as shared spaces where people work together to grow plants, and **Community Gardeners** as a community who are working together to grow plants in a shared space. This excludes individuals working in parallel in subdivided plots (such as allotments), and also excludes distributed communities or remote networks of individuals.

1.3 Method

Research in The Wild (RITW) seeks to explore current practice and future behaviour by disrupting existing practice with the introduction of novel technology (Rogers, 2012). We used Rogers and Marshall's recently published 2018 RITW framework to frame our approach and guide the nature of the exploration and disruption. We selected this particular RITW framework as it is the only extant RITW framework (Y. Rogers, personal communication, November 2018).

We started by focusing on the *In-situ* core base of the framework, and conducted contextual interviews at 5 sites across London, to investigate the current practices, goals and technology use of these groups. This was followed by a co-design workshop with community gardeners to elicit values and needs in relation to sensors in the garden. The co-design study mainly related to the Framework's *Design* and *Technology* core bases.

A room-scale experiment was then conducted to investigate the effects of providing data in an abstract setting (using findings from the earlier stages to cross-fertilise the *Theory* core base), and finally a provocative prototype was deployed in a community garden to elicit responses to different types of situated data in the wild, returning to the *In-situ* core base.

1.3.1 Research Questions

The overall research question for this research is *How can we design sensor and data systems for shared spaces that address the tension of non-use versus potential benefit in community gardens, and encourage use and appropriation by community gardeners?*

Given the exploratory nature of the main research question, it has been broken down into 2 separate, more specific, research questions.

RQ1: How can we design technologies to support Community Gardens?

What are the implications for designing sensor and data tools for the shared space of community gardens? We want to be able to provide recommendations for designing sensor and data systems for this domain.

RQ2: How can we design to support shared spaces?

Are there aspects of shared spaces that are important for design, and are there specific conceptual tools that can be developed and applied to shared spaces within the framework? We want to be able to provide conceptual tools that can be used to help think about design for shared spaces more generally within the RITW framework.

1.3.2 Reflective Practice

To address the research questions, a Research in The Wild approach was used. Research in the Wild typically involves the deployment of technology in a setting, using the methodology of 'probing' contexts, to change behaviour or enhance community practice. To help in this endeavour, Rogers and Marshall (2017) present an overarching framework that considers the different aspects involved. This is a recent, descriptive framework useful for characterising projects from a 'top down' perspective, but lacking in specific details of implementation. For instance, as part of the framework, Rogers and Marshall stress the importance of the design of the technology to be deployed. However, they do not detail *how* researchers should go about this, and the exact nature and design of the technology to be deployed can be difficult to specify despite being a "central concern" for RITW (Rogers and Marshall, 2017). This research seeks to adopt, adapt and make use of this new framework. As such, as part of this process, we will be engaging in what Braun and Clarke call "an ongoing reflexive dialogue on the part of the researcher or researchers" (Braun and Clarke, 2006). Each study chapter will reflect on the RITW framework and how it shaped the research, and how the framework can be adapted. This is formalised as an additional research question:

RQ3: How can we use the RITW framework when choosing and designing technologies for an In The Wild deployment?

We want to create extensions to, and techniques to work within, the RITW framework that can be used to help scaffold the design of the technology to be deployed into the field.

1.4 Contribution

There are two primary contributions of this thesis: **Domain Specific**, mainly addressing RQ1 and **Empirical**, mainly addressing RQ2:

1. **Domain Specific**

   Design implications for the specific domain; ways of designing technologies and platforms that are useful in a community garden context and will encourage adoption.

2. **Empirical**

   Conceptual tools and theoretical development for this and similar contexts that arose based on observations of situated and overview data in shared spaces; ways of thinking about these kind of environments, especially in terms of *situatedness*.

There is also a secondary reflective **methodological** contribution:

A. Methodological

Extensions to the Research In the Wild (RITW) (Rogers and Marshall, 2017) framework for design of RITW deployments, arguments for the value of this approach, and how this fits more broadly into a Research In the Wild approach

The **Domain Specific** design recommendations are a set of six key themes and implications for design, directly addressing RQ1. This contribution aims to address the gap in the literature on designing to support community gardeners with sensors and data, and present ways of designing to encourage adoption in community gardens. Previous research in this area has argued that this kind of technology is simply inappropriate for the context (Odom, 2010), and we should turn our attention elsewhere (Hirsch, 2014); however, by probing beyond current context and existing practices, we uncovered key themes and associated implications for design suggesting this is in fact a potentially fruitful area for HCI research and design, supporting the idea that technology and natural contexts are not incompatible *per se* (Bidwell and Browning, 2010). This also provides support for the value of ‘breaching’ methodologies that enable future exploration (Brown, Reeves, and Sherwood, 2011; Crabtree, 2004), and additionally offers an example of how the *disruption* of practice in RITW deployments (Rogers, 2012) can be beneficial in ‘wild’ contexts.

The **Empirical** contribution aims to answer RQ2 by focusing on the application of situated action (Suchman, 1987; Suchman, 2007) in shared spaces, and ways of extending situated action to help inform design in the wild. We found in our initial contextual research that action in community gardens is colocated and collaborative, in contrast to current paradigms which focus on individual interaction and remote collaborative behaviours (Klokmose and Zander, 2010; Lundgren et al., 2015). Situated action can help conceptualising behaviour in these settings; here we provide some ways of using situated action as a conceptual tool to help in constraining the design space when using the RITW framework. Specifically, we discuss the use of concepts of ‘situated’ versus ‘overview’ artefacts which arose from the contextual and lab research, and ultimately present the derived concept of ‘locality’ as a useful tool for understanding and designing data representation systems in shared spaces, based on the relationship between the degree of spatial binding of data and the ways this alters emergence of action. Collaboration research in HCI has tended to focus on *artificial proximity* (Mejia, Morán, and Favela, 2007), or where people are truly collocated the focus is on symmetric, co-temporal activity as a group whereas usage in the wild is *asymmetric* and distributed over time (Marshall, Morris, et al., 2011). This contribution offers a potential avenue for exploring interactions with data in shared spaces in the wild, and the different degrees of spatial binding can be used as a design tool to shape action in shared spaces.

The secondary **Methodological** contribution consists of reflections on the new Rogers and Marshall RITW framework (Rogers and Marshall, 2017), some extensions to the framework that arose from the reflection, and concrete applications of these extensions. We reflect on the use of a framework that attempts to describe RITW as a means of structuring and guiding a RITW research process; in other words, the adaption of a *descriptive* framework to use as a *normative* one. This secondary contribution serves to both attempt to make the motivations, evolution and constructed nature of the research more explicit (Braun and Clarke, 2006), and also to provide tools that can be adopted or adapted by others seeking to use the RITW framework in a normative manner. In particular, ways of approaching the selection and design of technological prototypes and deployments, which is identified as a central concern for RITW by Rogers and Marshall (2017).

1.5 Thesis Structure

This thesis is made up of 9 chapters (including this one), as shown in Figure 1.1.

Chapter 2 presents a **Literature Review** of related work and previous research. This chapter focuses on three relevant areas: Research in HCI in the garden, theory and research into action in shared spaces, and Research In The Wild.

Chapter 3 deals with the **Methodology** of this thesis, both the overall approach and the motivation and rationale for research methods for individual studies.

Chapters 4 to 7 describe each study in more detail:

Chapter 4 details the initial **Contextual Interviews**, which were undertaken in 5 different community gardens to understand existing practices.

Chapter 5 describes a **Design Workshop**, investigating responses to novel technologies and concepts amongst community members.

Chapter 6 presents an **Experiment** intended to look into a particular aspect that arose from the interviews and design workshop; specifically

1 **INTRODUCTION**

2 **LITERATURE REVIEW**
Previous research and related work

3 **METHOD**
Overall approach

STUDY CHAPTERS

4 **CONTEXTUAL INTERVIEWS**
Interviews in 5 community gardens to establish context

5 **DESIGN WORKSHOP**
Co-design workshop to elicit responses to novel tech

6 **EXPERIMENT**
Study on the effect of data representation on the emergence of action in a co-located collaborative task

7 **PROVOCATIVE PROTOTYPE**
Deployment of a Provocative Prototype in a community garden

9 **DISCUSSION**
Discussion of results and relation to research questions

10 **CONCLUSION**

Figure 1.1: Thesis Structure

the effects of overview vs situated data representations on the emergence of action in a co-located collaboration task.

Chapter 7 presents a **Provocative Prototype** study, where prototypes were deployed into a community garden. This chapter discusses design and methodology considerations for a provocative prototype, and reports the Provocative Prototype study itself.

Chapter 8 presents a **Discussion** of the results from the study chapters, implications for design for community gardens, situated and overview data in shared spaces, and reflections on the RITW framework. This chapter present contributions of the thesis, and relates these back to the research questions.

Chapter 9 is the **Conclusion**, summarising the thesis and placing the findings in a broader context.

1.6 Summary

This thesis investigates the tension of benefit versus non-use of sensors in community gardens, using a mix of methods within a RITW framework. We discuss not only specific considerations for designing appropriate sensor interfaces for community gardens, but also conceptual and methodological tools for investigating shared environments more broadly within a Research In The Wild framework.

2 Literature Review

This chapter presents a review of literature relevant to sensors and data in the shared spaces of community gardens. First, existing research on *HCI in the Garden* is considered to establish domain context and relevance, then research into *Shared Spaces* is reviewed in two parts: firstly, ways of understanding these spaces and action within them; and secondly, ways in which these spaces can be augmented. Following this, *Research In The Wild* methodology is discussed.

2.1 HCI in the garden

The first section in this literature review looks at research in HCI in community gardening, to understand what has been done already in this domain and how it applies to our research area. It covers why gardens are of interest to HCI, the potential benefits of sensing technology in gardening, and issues of non-use and technology rejection in previous research. We also examine some existing systems, and establish that there is a focus on designing for individual decision making rather than shared spaces.

2.1.1 Growing in HCI

Designers and technologists are increasingly interested in urban agriculture, but there has until recently been little interest amongst HCI researchers (Hirsch, 2014), and there is a paucity of work on the design of interactive systems in the context of small-scale urban food production (Odom, 2014). Very recently however, urban agriculture has been emerging as an area of interest for HCI (Odom, 2014), as has sustainable HCI more generally (Choi and Blevis, 2010).

Hirsch (2014) argues that an emphasis on individual cultivation and community gardening in previous work, as opposed to the broader framework of 'urban food provisioning', limits the scope of HCI research; cultivation is only one of the opportunities for study and design at many points in the food supply chain (Hirsch, 2014). Beyond the garden itself, there are issues of distribution, policy and economics - for instance, getting food to market is an issue for small local farmers due to the complexity of supply chains (Patel, 2013) and the unpredictability in yields and quality control which makes meeting sales agreements difficult (Campbell, 2013). Indeed, Hirsch (2014) suggests that design interventions in the cultivation part of the chain might be challenging due to technological resistance. Designing for more collaborative, situated interaction may be one approach to addressing this challenge.

DiSalvo, Sengers, and Brynjarsdóttir (2010) and Goodman (2009) argue that sustainable HCI and interaction design has tended to focus on the individual as a consumer and associated behavioural change - DiSalvo, Sengers, and Brynjarsdóttir (2010) go on to suggest that investigating areas which are outside of this individual consumer model would be much more interesting[1].

It has been argued that technological solutions can support decision making and improve the chances of viability in community food growing (Campbell, 2013; Lyle, 2013). A number of technologies have been developed to help farmers and gardeners make planting decisions and assist with maintenance, such as 'Precision agriculture' sensing and analysis techniques used in agribusiness (Seelan et al., 2003). However, despite demonstrated benefits in commercial settings ranging from large agricultural concerns (Seelan et al., 2003) to smaller horticultural businesses (such as vineyards, (Burrell, Brooke, and Beckwith, 2004)), this kind of technology so far has not trans-

[1] Hirsch posits that community gardening isn't interesting because it doesn't involve collective activity (Hirsch, 2014), which appears to be in direct contradiction to descriptions elsewhere (e.g. (Campbell, 2013; Odom, 2010)). This seems to be an issue of terminology rather than controversy; Hirsch (2014) is characterising 'community gardens' as projects where "individuals managed their own subplots" and thus were engaging in *parallel* rather than truly *collective* activity; it appears that American English uses 'community garden' where British English (and other Commonwealth variants) would use 'allotment'. This thesis uses 'community garden' in the sense of spaces where *collective* activity is being undertaken.

ferred well to a community context (Campbell, 2013). Growers often do not consider computing technologies as relevant to their practice (Pearce and Murphy, 2010), and several urban agriculture communities are opposed to 'technological augmentation of their practice' (Odom, 2010). Odom (2010) reports that growers worry that environment sensors will lead to an over-reliance on these technologies which would prevent community members developing an intuitive understanding of the environment through continued interaction with the growing space. Senior community members they interviewed were also concerned that such systems would interfere with learning by new community members, as they felt such a system would get in the way of educative interactions between new and experienced members. Despite the putative benefits to supporting decision making in community growing groups, Odom (2010) concludes that directly augmenting practice in this space is neither appropriate or beneficial.

Considering technological resistance, both Odom (2010) and Goodman and Rosner (2011) observed resistance to technological augmentation of practice in community growing groups. Odom (2010) argues that this is due to community members feeling that introducing technology to the growing space will make things 'too easy', prevent the development of holistic understanding of the environment and interfere with community building and learning interactions that occur between people in the growing space. People worry that 'Technology' will take away from the essence of the activity; it will prevent 'getting hands in soil' (Goodman and Rosner, 2011). The weight of argument appears to be suggesting that this is not a suitable space for the introduction of novel technology, and indeed both Hirsch (2014) and Odom (2010) assert that plot/garden level sensing technology is not appropriate for urban agriculture groups. However, Goodman and Rosner (2011) argue that although participants expressed concerns about technology, they were actually observed interleaving 'technology' with their practice. Rejection seems to focus around automation, the removal of agency and the adding of intermediation between the person and their chosen task - for instance, Goodman and Rosner (2011) describe one gardener's rejection of automatic watering /weeding systems "I don't want to be cut free. I might want to be informed, but I want to have an engaged relationship"

Hirsch (2014) posits that the resistance is due to the 'hobbyist' nature of the groups, and that more commercial entities may not be as resistant. Indeed, research on sensor networks in vineyards has shown that optimisation and automation were desired in this more commercial context (Burrell, Brooke, and Beckwith, 2004). However, there were still some aspects that participants felt should never be automated - for instance, when to harvest is always a 'judgement call' that growers wanted to make themselves. There are also echoes of situated awareness and a weak version of "getting close to the soil" - you 'can't farm remotely' as there is a need to visit, see and touch the crop (Burrell, Brooke, and Beckwith, 2004).

Bidwell and Browning (2010) argue however that it is the specific *design* of many technologies that is inappropriate to a 'natural world' context, rather than technology itself. There may be design solutions which support and augment practice whilst fostering acceptance and encouraging adoption and appropriation; the issues of reduced interaction in the growing space (both with the environment, the plants themselves and between community members) assume the output of such devices is presented *outside* of the growing space. Feeding back information directly in the growing space may support development of a holistic understanding of the environment by increasing the availability of intangible variables and the granularity and temporal scope of tangible variables, and offer additional opportunity for in-situ questioning by new members rather than reducing those opportunities. Rejection of 'technological augmentation of practice' (Odom, 2010) appears to be driven by fears that the technology will interfere with the relationship with the growing space through automation and the reduction of agency, and thus be detrimental to learning, community building and the experience of 'getting close to the soil'. Community growing groups make decisions collaboratively and while situated in the growing space. These decisions are perceived as being ad hoc, but are informed by knowledge about the space and the domain. Technologies designed for commercial agriculture are focused on *automation* and *optimisation*. Many of the technologies used in agribusinesses are designed for optimising yield and reducing variability in crops - the highly technological and process based methods for doing this are the type of things that people involved in community projects are trying to escape from, and do not map well onto the collaborative, in situ decision making in the garden. Introducing technology into the environment, as can be seen with the 'smart' city paradigm, "changes the nature of place" (Mullagh, Blair, and Dunn, 2014), and there can be too much focus on technology, not enough on the humans who inhabit the spaces. Mullagh, Blair, and Dunn (2014) argues that this paradigm is biased towards *efficiency* instead of *effectiveness*, and "does not always provide optimal environment for citizens".

2.1.2 Existing sensor and data tech in the garden

As discussed in the *Collocated Collaboration* section below, much current technology is designed to support *remote* interactions, not *collocated ones* (Lundgren et al., 2015), with the goal of creating 'artificial proximity' (Mejia, Morán, and Favela, 2007) between remote collaborators. The prevailing paradigm is still based on one person, one computer (Klokmose and Zander, 2010), even when linking those people together. This focus is not restricted to industry; (Sengers et al., 2004) argue that HCI traditionally centres on designing for the individual (as a natural result of a focus on *the user* (Sellen et al., 2009)), and much work on persuasive and ambient technologies focuses on individual resource consumption (DiSalvo, Sengers, and Brynjarsdóttir, 2010) (Goodman, 2009). This single-user focus extends to garden technology at both a large commercial scale and in consumer devices.

At a large commercial scale, both remote sensing and sensor networks are used to provide information; hyperspectral imaging (typically from satellites or aircraft - see Figure 2.1) is used to identify the amount of photosynthetic activity in certain areas, which can be used as a proxy measure of plant vigorousness, and therefore allowing various inferences to be made about local growing conditions (Seelan et al., 2003). Sensor networks can also be deployed to sample local conditions more directly, as in the Burrell, Brooke, and Beckwith (2004) study mentioned earlier. These technologies are designed to support *individual decision makers*; organisations are seen as hierarchical with data being used by leaders to make decisions, which are then cascaded down to other levels of the hierarchy. Burrell, Brooke, and Beckwith (2004) do identify different 'human touchpoints', where workers with different roles interact with the sensors differently; they describe that managers want data that suggests a tangible next step rather than actually performing automatic actions, whereas workers are used as part of the system as input (by tracking their movements) and potentially as 'data mules', wearing devices that can communicate with sensors as they pass, then passing that data on to a hub in a central area[2]. This approach may be suitable for organisations with well defined roles and hierarchies, but community organisations are more diffuse.

At the other end of the scale there has been a recent surge in interest in sensing and irrigation technology for individual consumers (for instance, the Edyn sensing/watering device[3] was backed on crowd-funding platform Kickstarter for over 300% of its funding goal at the outset of this PhD research, making it the most backed agritech product on Kickstarter at the time. There are a wide variety of similar systems which use a smartphone or other screen-based device, for example the Koubachi WiFi moisture sensor, the now-defunct Parrot, and the similar but more recent Xiaomi

[2]They also discuss using dogs for the same purpose. The use of the term 'mules' (due to both its meaning as low status beast of burden *and* the connotation of 'dumb carrier' as in terms such as 'drug mule') and the immediate reference to dogs shows the low level in the hierarchy of the workers, which is at odds with a community setting. Additionally, the language reinforces the impression that Burrel et al's 'touch points' are about *organisational roles* with the people actually tending the plants not involved in the use of the data and sensors. Although in a community project different people will have different levels of involvement in decision making, and have different skill levels and interest in assessing local conditions, all members have at least *in principle* the potential to be involved.

[3]http://www.edyn.com/

Figure 2.1: False colour images of a research farm from NASA, showing near-infrared. These kinds of images can be taken from satellites, aircraft and Unmanned Aerial Vehicles (UAVs, known colloquially as 'drones') using multispectral or hyperspectral sensors which see much more of the electromagnetic spectrum than the naked eye. Different wavelengths can be used to make inferences about factors such as crop vitality and moisture levels. In this image, the crops appear red and the darkness of the red indicates moisture - you can see the Eastern (rightmost) part of field 31 gets much more water than the Western side.

Wireless Plant Monitor. Koubachi was recently acquired by Gardena, to integrate into their larger 'smart garden' product Gardena Smart Garden[4], which has a focus on watering, sprinklers and mowing.

These systems typically use remote databases and modelling for specific plant types, however the complexity of this tends to be masked from the user; instead the apps direct the user or automate processes entirely. Even completely automated planters (such as the hydroponic Click and Grow[5]) are available to consumers.

Automation

Existing technologies have a strong focus on *automation* and *optimisation*. Many of the technologies used in agribusinesses are designed for optimising yield and reducing variability in crops - the highly technological and process based methods for doing this are the type of things that people involved in community projects are trying to escape from. People engage in community agriculture projects in part to build a closer relationship with nature, and to escape from the technology in their daily lives. Consumer devices and apps either do it for you, or tell you exactly what to do. This often is not desirable in a community growing context, since getting close to the soil and learning about the growing systems are primary motivators. These technologies are essentially reductive - they use a mass of complex data on the interconnected growing system, and hide it from the user, translating it either into direct intervention or highly directed intervention. As such, the agency of the user is reduced, and their relationship with the system is reduced simply to one of ownership rather than tending.

The Nest thermostat is a recent example of an automating technology, that also attempts to direct the user. It provides extra functionality over traditional thermostats, and automatically manages home temperatures with a goal of reducing costs and environmental impact through efficiency. Addi-

[4]http://www.gardena.com/uk/products/smart/
[5]http://www.clickandgrow.com/

Figure 2.2: The nest thermostat, showing current temperature on the radial and the systems's assessment of whether people are in the house. Note the leaf icon indicating that the household is 'saving energy'. Image from Nest's press pack (see *https://nest.com/uk/press/#product-images*)

tionally, it attempts to enact behaviour change by rewarding decisions that are 'better' from a cost/environment point of view - when you are 'saving energy', you are rewarded with an image of a leaf Figure 2.2. According to the Nest website[6] : *"The Leaf will challenge you to choose temperatures that are a little lower than you're used to."* A longitudinal study of new Nest users (Yang, Newman, and Forlizzi, 2014) showed that whilst the Nest led initially to increased engagement with household HVAC (heating, ventilation and cooling) settings and schedules, this behaviour change did not last, with some users reporting lack of engagement after only 2 months. Yang, Newman, and Forlizzi (2014) argue that this was not only due to novelty effect wearing off, but also due to users coming to rely on the automation to the point where they no longer thought about the Nest at all. Participants stopped paying attention to the leaf - for instance, one participant interviewed at 15 months said they *"...haven't checked the schedule or the green leaf... It kind of faded into the background for me".* This lack of engagement led to users not adjusting the Nests schedules or changing the temperature to be more eco friendly. They were not being "challenged" by the leaf because the Nest's automation meant they were not thinking about the HVAC system *at all*. When reflecting on the history of the Nest over the time, participants were surprised at how inefficient their usage was. Yang, Newman, and Forlizzi (2014) observe that had they not run the follow up interviews, participants were unlikely to have realised that the Nest's automation was not working as well as they thought - users' *perception* was that the automation was saving energy, whereas this was not always the case.

Sustainability work in HCI

The majority of work on sustainable HCI has been on persuasive and ambient technologies, focused on individual resource consumption (DiSalvo, Sengers, and Brynjarsdóttir, 2010). Nest is an interesting example of this kind of technology, as it covers both what DiSalvo, Sengers, and Brynjars-

[6]http://support.nest.com/uk/article/How-does-the-Nest-Leaf-work

dóttir (2010) describe as 'user as problem' and 'solving users' problems' approaches - the augmented thermostat functions save users money and make them more comfortable, but the leaf tries to 'fix' their problematic behaviour. The Nest's reward mechanism is more subtle than some of the commercial devices/apps for garden sensing in that it is persuasive/ambient rather than directly dictatorial - the Koubachi[7] for instance implores its user to 'water [your plant] now!' - but ultimately, although the Nest allows the user to learn about their own patterns of consumption and alter their behaviour, there is no scope for creativity or wider learning. The device *automates* and *directs*, enhancing the user's life in a fairly passive manner. There is also some evidence that users cannot comprehend the black box learning model of the Nest (Yang and Newman, 2013) leading to some people setting inefficient manual breakpoints because they feel the Nest is 'wrong' (Yang and Newman, 2013) and others never updating the Nest's schedules because they trust the automation *too* much (Yang, Newman, and Forlizzi, 2014).

In opposition to *automation* is *empowerment*. Rather than *doing something for* a user, tools can empower a user to *do it themselves*. An example of this is the spreadsheet - this represented a revolutionary tool at its inception (Figure 2.3); people without a technical background were empowered to produce powerful numeric simulations to their own requirements (Zynda, 2013) - for instance, a small business owner could model their revenue over the course of a year, and tweak variables to see what effects different decisions and external variables might have. Unlike the Nest, the spreadsheet doesn't *do* anything on its own. There are no rewards for 'good' behaviour - the intrinsic rewards of achievement and any benefits resulting from the use of the spreadsheet are related to solving the problem at hand, not using the spreadsheet itself.

Existing consumer technology is more like the Nest thermostat - it can certainly help you to optimise your plant care, by telling you what to do and when. (or by automatically doing it for you). What it doesn't support

[7] http://www.koubachi.com/

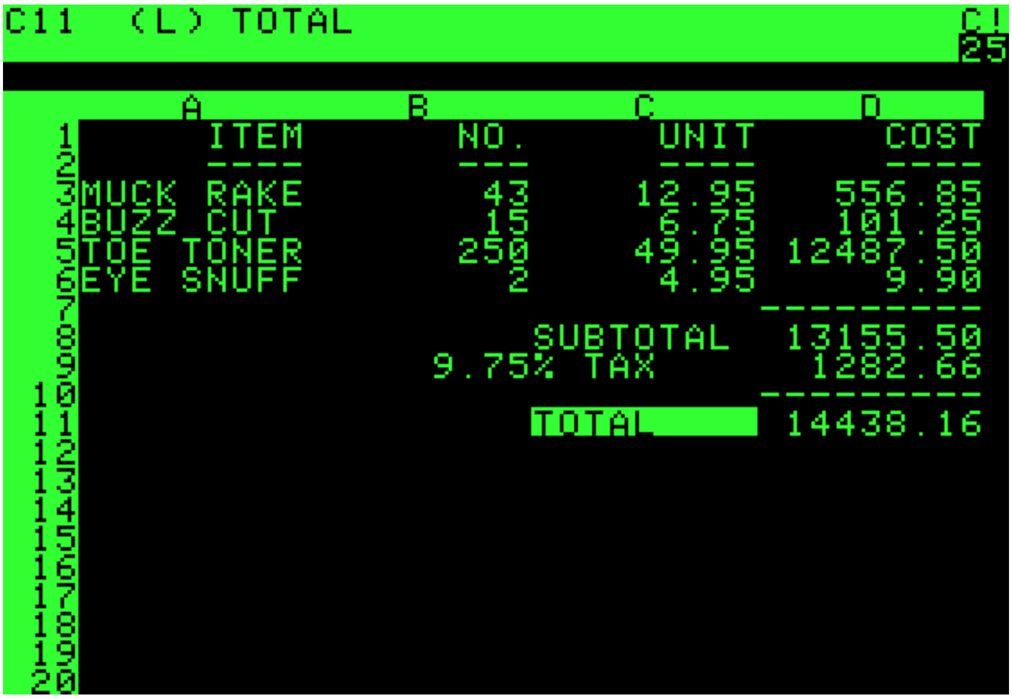

Figure 2.3: Visicalc. The first ‘electronic spreadsheet’. Image from wikimedia commons

so well is *empowering* its users. Existing agri-industrial technology is like this when hooked into automated systems, but it can also be more like the spreadsheet in some ways, in that it provides a lot of information but not necessarily any idea of what to do with it. (In fact, a lot of the time the data from such systems ends up in a spreadsheet!).

It appears that technological resistance, rather than being a reason *not* to do research in the cultivation area of the food provision chain actually presents an opportunity for design.

2.1.3 Situated data in the garden

The rejection of 'technological augmentation of practice' (Odom, 2010) discussed in the previous section appears to be driven by fears that the technology will interfere with the relationship with the growing space through automation and the reduction of agency (Goodman and Rosner, 2011), and thus be detrimental to learning, community building and the experience of 'getting close to the soil'.

Instead of hiding the variables in the garden in systems that tell you what to do, or revealing them in raw form outside of the growing space, making some of these intangibles (or semi-tangibles - for instance, expert gardeners can tell if soil is 'moist enough' by sticking their finger in it; novices may be able to distinguish 'bone dry' and 'soaked' but nowhere in between) directly tangible within the growing space. This can help understanding and integration of the complex interdependencies of the growing environment (of which the growers are a symbiotic part). Expert growers have a 'feel' or 'intuition' for the variables that need to be balanced, however novice users of the space need support in understanding these characteristics - as experience levels increase, specific sensing tools become supplanted by intuitive understanding (Kuznetsov, Odom, et al., 2011). Experienced growers may be able to gain extra insight by moving factors into an external representation (Elmqvist, 2011).

Many commercial plant sensors for consumer use (such as the Koubachi and the Edyn mentioned earlier) offload their display requirements onto the users' existing devices - smartphones/tablets or computers. Agricultural sensor packages at the industrial level (such as those made by Delta-T[8]) tend to be designed to output to ruggedised hand held displays or to data loggers for later processing typically in general purpose spreadsheet software. Using tablets and phones as screens for headless sensors (sensors that lack their own human interfaces but can communicate with other devices) and to make intangible 'stuff' tangible often makes sense; making use of the networked input device already in people's pocket reduces barriers to uptake and increases the likelihood that people will adopt the technology (Balestrini, Bird, et al., 2014). However, growing environments are not the natural habitat of phones, tablets and laptops. Humid, damp, muddy and messy conditions are less than ideal for whipping out an iPhone, and gardening gloves are unlikely to be equipped with capacitive areas. More importantly, these kind of devices are primarily designed for *single users* and do not support local collaborative interaction. In order to impart a shared autobiography, data representations need to be physically present within the space.

In conclusion to this section on *HCI In The Garden*, we can identify a gap in the literature relating to sensor and data technology in community gardens; There is as yet little HCI work in the area of sensors and data in community gardens (Hirsch, 2014), and it has been argued that 'technological rejection' by community gardeners makes this an unsuitable area for further study (Odom, 2014). However, technology in and of itself is not rejected by gardeners (Goodman and Rosner, 2011), it is the disconnect with the natural world (Bidwell and Browning, 2010) induced by single-user focused design paradigms (Robinson, Marsden, and M. Jones, 2014) that is rejected. As such, there is an opportunity to explore how we could design systems that will have the potential to be adopted rather than rejected by focusing on the garden as a *shared space* where gardeners *collaborate* within it.

[8] http://www.delta-t.co.uk/

2.2 Shared spaces

Shared spaces are increasingly an area of interest in HCI; with the ubiquity of mobile technology and the advent of 'the Internet of Things' and technologies embedded into the environment. Whilst there has been much academic research into supporting collocated collaboration (Rogers, W. Hazlewood, et al., 2004; Lundgren et al., 2015), consumer technology is often designed to support remote rather than collocated interactions (Church, W. R. Hazlewood, and Rogers, 2006; Mejia, Morán, and Favela, 2007): the prevailing design ethos remains focused on individuals using an app on a device. This section considers how we can understand and augment shared spaces from the perspective of colocated collaboration.

2.2.1 Understanding action in shared spaces

An area that lends itself to being analysed in terms of collaborating in shared spaces is *community gardening*. In particular, community gardening groups are situated and collaborative, and working together in the growing space is highly valued by members of these communities. Indeed, it is possible that lack of support for collocated collaboration is one of the reasons that technology in this area is rejected. In order to design to support this kind of collaboration, it is necessary to examine existing work in the area.

There are a number of theoretical approaches in HCI to colocated collaboration, such as Distributed Cognition (DCog) (Hutchins, 1995) and Activity Theory (Kaptelinin and Nardi, 2006). In practice, any of these could be valuable for framing action in shared spaces, but situated action (Suchman, 2007) was selected for this thesis as it mapped most closely onto behaviour observed in early phases of the research; the focus on context and emergent action is applicable to the less structured environment of the garden, where actions are spread out over time and volunteers goals and tasks are not as strictly defined as in a work environment. Situated action is also flexible - it's explicitly not intended to be a 'hardened theoretical construct' (Suchman, 2007), thus it doesn't enforce a particular mode of study or analysis on the diverse garden contexts.

Situated Action

The core idea behind situated action is that planning and action are *not* separate processes; humans are not rational decision makers analysing a situation, making plans then executing them. Rather, all of our actions arise out of our *contingent circumstance* - which includes our perceptions of our surroundings, our knowledge and memories, and our application of analytic thought (Suchman, 2007).

Some have criticised this emergence of action as eliding motive, emotion and agency, and ignoring the role of creativity (Kaptelinin and Nardi, 2006). However, this criticism stems from a mischaracterisation of the nature of contingent circumstance: Suchman was not arguing that there is no such thing as planning or analysis, nor that that such activities have no impact on our action, but rather that these are not 'specially privileged' classes of cognition, but simply part of the overall contingent circumstance that leads to action[9]. J. E. Bardram (1997) argues that plans are vital to 'realising work', but that plans themselves arise out of situated action (and feed back into it as part of the contingent circumstance).

Suchman gives the example of canoeing down rapids - before entering the rapids, the canoeist considers the path they will take and may plan in great detail, but once in the rapids themselves they respond to the circumstance using embodied skills rather than act out the plan. Rather, the plan is a resource allowing the canoeist to put themselves in a position to apply their embodied skills effectively; it is both part of the contingent circumstance, and also a way of shaping the situation for favourable outcomes.

[9] Suchman added the concept of 'contingent circumstance' in the 2nd edition of *Human-machine reconfigurations: Plans and situated actions*, to address the issue that her description of action in the 1st edition as being 'ad hoc' had led to the interpretation that situated action was *purely* based on immediate environmental stimuli, completely discounting analytic thought and 'internal' states.

This concept of *contingent circumstance* is useful for considering community gardens, where there is a shared space, but interactions within it are spread out over time and different people. However, it was developed out of office task use cases, with single user, task focused, single-machine dialogue. More recent work also focuses on traditional 'work' contexts, similarly to DCog, which lends itself to settings where there are systemic goals such as piloting a boat into a harbour (Kaptelinin and Nardi, 2006), and assigned tasks within a hierarchy (Moran, Nakata, and Inoue, 2012). With increasingly complex interactions of multiple machines and multiple humans, these theories (or how we apply them) need to be adapted to more complex, less structured and broader spatial and temporal scopes (Furniss et al., 2015).

Community gardens are a shared space where the actions of volunteers *change* the space; not only can the place itself be shaped with the intent of changing people's behaviour (such as with signs or notes), but any actions performed in the space change it and thus alter the contingent circumstance. This is another area where situation action maps particularly well onto the domain: an important part of situated action is that ongoing action shapes the situation even as it is shaped *by* the situation (Suchman, 2007; Clancey, 1993). The garden presents a physical manifestation of this, and represents a large part of the physical aspect of the evolving contingent circumstance, which can anchor our analysis.

2.2.2 Augmenting shared spaces

So how should we use this theoretical framing to understand shared spaces such as the garden? This section considers a range of work that seeks to use theory to inform how to augment shared spaces, focussing on different modalities and types of deployment. First, approaches to colocated collaboration in HCI in general are discussed, then research on modalities and representations used in augmenting shared spaces.

Collocated collaboration in HCI

Much of the literature on computer supported collaboration focusses on overcoming the barriers to collaboration in remote collaboration (Church, W. R. Hazlewood, and Rogers, 2006) where the goal is to gain the benefits of remote collaboration whilst adhering as closely as possible to the experience of fully local collaboration (what Mejia, Morán, and Favela (2007) describe as 'providing *artificial proximity*'). Some systems attempt to provide this in an abstract form by introducing aspects of local communication (such as Social Translucency) to collaboration systems - such as Erickson et al. (2002)'s 'social proxies' in their Babble system - whereas others attempt to make the shared reference frames physically match as closely as possible, such as O'Hara, Kjeldskov, and Paay (2011)'s Blended Interaction Spaces. Their Halo system uses mixed reality to attempt to replicate the physical/digital space in two remote rooms as closely as possible, seeking ultimately to make participants feel they are sharing the same space.

Whilst there has been much academic research into supporting collocated collaboration (Rogers, W. Hazlewood, et al., 2004; Lundgren et al., 2015), consumer technology remains focused on supporting remote rather than collocated interactions (Lundgren et al., 2015; Klokmose and Zander, 2010). Robinson, Marsden, and M. Jones (2014) see this 'digital primacy' as leading not just to *distraction* from the real world via the (seemingly) more compelling and dynamic world within a device, but to the physical world becoming 'less real' for users. They give the example of a tourist couple observed in a cafe in Paris who although physically co-present, spent the whole time interacting with remote networks on their phones rather than interacting with each other or engaging with the environment. Houben, Tell, and J. Bardram (2014) argue that this one-person-one-device paradigm is not even reflective of current use cases, as *"The user-device mapping is quickly changing from being a one-to-one to a one-to-many or even to a many-to-many relation"*, but that common consumer tools (such as Dropbox) still use traditional paradigms that do not support this emerging device/user ecology. This single (local) user focus is problematic in shared spaces, as systems designed for single user interaction are sub-optimal when used as part of collocated collaboration (Rogers, Lim, et al., 2009), in part as they introduce inequity of interaction (*ibid*). Similarly, research seeking to collaboratively gather (or 'crowd sense') data is focused on facilitating and incentivising the collaborative collection of data by remote participants (W. Willett et al., 2010), rather than supporting colocated collaboration between those participants. It has been argued that while this can provide valuable datasets to researchers, the *participants* in this kind of crowdsensing struggle to interpret the data (Balestrini, Diez, and Marshall, 2014) or to use it to inform action (Aoki et al., 2009).

Rogers, Lim, et al. (2009) describe three types of 'shareable interfaces' specifically designed for collocated collaborative use: large wall displays, multitouch tabletops and tangibles. Large displays are increasingly popular in urban settings but often remain underused or unused due to display blindness and evaluation apprehension (Koeman, Kalnikaité, et al., 2014). 'Display blindness' is a phenomenon where people do not attend to situated displays, due to the expectation that they will show advertising content (Müller et al., 2009). More recent eye tracking studies have shown that participants are not strictly 'blind' to the displays, but that their fixations on them are very short and thus likely to be unconscious and part of navigating the environment rather than directed attention (Dalton, Collins, and Marshall, 2015). 'Evaluation apprehension' is defined by O'Hara, Glancy, and Robertshaw (2008) as *"…a fear of their behaviour being judged by social others in the vicinity witnessing the behaviour."*: social embarrassment is a key factor in preventing people from interacting with public displays (Brignull and Rogers, 2003). Despite the potential to engage and inform, the problems of first capturing attention, then overcoming social embarrassment means that getting people to actually *use* public displays is challenging (Rogers and Rodden, 2003). Additionally, it has been argued that even if these issues are overcome, large interactive surfaces are not flexible enough to support the kind of ad-hoc interactions that take place in group collaboration (Brudy, 2015).

Interactive tabletops have been shown to support collaborative decision making, by providing equitable interaction with shared information (Rogers, W. Hazlewood, et al., 2004), however despite being 'heralded as an innovative technology … there is little evidence of these materialising outside of research lab settings' (Marshall, Morris, et al., 2011). Much of the research on tabletops is in a lab setting, and Marshall, Morris, et al. (2011) found that 'group' interaction was far more asymmetrical in the wild, with people not approaching the interaction as a coherent group, leading to breakdowns in the interaction as the table's design model was unable to accommodate these asymmetric interactions[10]. As with the horizontal surfaces, the tabletop appears to not support the ad hoc nature of collaboration in the wild (Brudy, 2015).

Hornecker and Buur (2006) argue that "the support of social interaction and collaboration might be the most important and domain-independent feature of tangible interaction", and Rogers, Lim, et al. (2009) showed that adding physical features to a collaborative design task promoted more equitable verbal interaction than a laptop or tabletop only interface, and argued adding tangible elements helps support coordinated joint actions. Rogers, Lim, et al. (2009) also found that although physical equity was not higher than the tabletop condition, the patterns of interaction suggested that people with less verbal interaction showed more physical interaction in the tangible-digital condition, suggesting that tangible items encourage more participation from excluded group members. Tangible interfaces would appear to be more practically useful in plant-growing environments, but Paay, Kjeldskov, and Skov (2015) go even further and discuss systems which provide 'ambient and instrumental additions' for collaboration (whilst cooking, in this case) based on interpreting the proxemics of the collaborators; not only is this practical as "Their hands go through various stages of business, wetness and messiness", but also supports a more meaningful and positive experience by supporting existing practice rather

[10]the video of this is great fun to watch.

than altering it. However, Paay, Kjeldskov, and Skov (2015) do not discuss the *nature* of this ambient and instrumental addition, or what form it might take. In the simplest case, proximity to a region of interest could invoke a representation of locally relevant data, the nature of which could be differentiated based on the formation and proxemic structure of the collaborators.

In summary, collaboration research in HCI has tended to focus on *artificial proximity*, or where people are truly collocated the focus is on symmetric, co-temporal activity as a group[11]. However, collaboration in the wild differs as it is *asymmetric* and distributed over time (as in Marshall, Morris, et al. (2011)), and ad-hoc in nature (Brudy, 2015). Shared spaces such as community gardens may represent an interesting domain to examine this kind of complex collaboration in the wild.

Modality and representation

Approaches to analysis and display of local data often focus on using screen based devices such as phones or computers that people already have. Mobile devices are particularly compelling as they are available both for contextual access in the environment and access later in other contexts such as the home or office. Although this use of the hardware in people's pocket lowers barriers to entry (Balestrini, Bird, et al., 2014), such interfaces do not facilitate collaborative explorations and analysis. Moreover, these 'powerful representational reality spaces' can disrupt the user's cognitive-affective relationship with the physical space they are in (Bidwell and Browning, 2010); this is especially problematic for communities where presence in the environment is part of the appeal (such as community growing groups (Odom, 2010)).

Dedicated screen-based displays are also commonly installed in public environments (Seitinger, Perry, and Mitchell, 2009), however digital displays

[11] It is interesting that in some ways this mirrors the focus in e.g DCog on structured tasks. In part this could be due to a focus on work contexts, but also may reflect our bias as observers towards atomic, observable events.

of this type lack suitable affordances for informing or engaging people in public settings (Koeman, Kalnikaité, et al., 2014; Seitinger, Perry, and Mitchell, 2009), often resulting in being ignored and unused (Koeman, Kalnikaité, et al., 2014). A number of alternatives to urban display and interaction have been explored, including networks of interactive light nodes (Seitinger, Perry, and Mitchell, 2009), chalk street-art (Koeman, Kalnikaité, et al., 2014) and wall crawling robots (Kuznetsov, Paulos, et al., 2010). These three examples augment existing aspects of the environment, using surfaces as substrates for display and interaction. Rather than attaching a window into an abstract representational space, they add data and interactivity to the environment itself. Similar modular, responsive artefacts could be used to facilitate collaborative analysis in an appropriate and engaging manner, for instance sensor network user interfaces (SNUIs) where the sensors themselves are part of the interface (Merrill, Kalanithi, and Maes, 2007)[12].

We are looking for different ways to augment the space; here we discuss a (non-exhaustive!) selection of different possible interaction approaches, broadly grouped into **Audible**, **Tangible** and **Visual** representations.

Screenless data representations of plant and environment data as sonifications have been developed, e.g the oxygen flute (Niemeyer, 2001) which responds to co2/o2 levels,Variable 4[13] which uses environment variables as generative music input (Bulley and D. Jones, 2011) andLiving Symphonies[14] which uses entire forest ecosystems as an input. Sonifications are potentially useful for environmental data because they take advantage of the human audio systems ability to extract patterns and changes over time (Walker and Nees, 2011), and may be particularly appropriate to this

[12] Arguably, the devices described in (Merrill, Kalanithi, and Maes, 2007) are *not* SNUIS - the siftables more resemble a kind of distributed tangible interface since the sensors are entirely in service to the *interaction*. The StickEar in Yeo, Nanayakkara, and Ransiri (2013) is actually closer to Merrill, Kalanithi, and Maes (2007) own description of a SNUI.

[13] http://www.variable4.org.uk/

[14] http://www.livingsymphonies.com/

context because they are usable whilst performing other tasks (Walker and Nees, 2011). An additional interesting quality of sonifications that may be applicable to the garden context is that they can be produced not just by playing from a speaker, but from fairly static physical designs (in the Acoustic Barcode project, the audio is generated entirely by a human rubbing a stick over a notched piece of material (Harrison, Xiao, and Hudson, 2012)).

However, sonifications can be difficult to interpret without training and there is a general lack of guidelines for designing these kind of auditory interfaces (Smith and Walker, 2005) and may not even be recognised as information carrying. Additionally, designing sonifications that directly correspond to the space that are capable of being 'zoomed out' for an integrated understanding is complex. Zhao et al. (2004) describe using 'gists' as short data overviews within a spatial sonification system, however not only is this in a digital space with complete control of the soundscape but also the nature of the overview 'gist' and the locally presented data is different, so one-to-one mapping between the different representations is not preserved.

Tangible representations have also been widely used for data representation (Houben, Golsteijn, et al., 2016). Tangibles offer potential benefits as they leverage our perceptual exploration skills (Jansen et al., 2015), however Marshall, Rogers, and Hornecker (2007) argue that there is little evidence that these benefits are observed in practice. Jansen et al. (2015) also observe that potential benefits need to be weighed against the costs involved in the creation of physical data representations.

Although *screen* displays are visual, here we will discuss some approaches that are visual but integrated into the environment rather than being a 'screen' display. One approach uses what Seitinger, Perry, and Mitchell (2009) call 'physical pixels'; by applying a network of lights to an existing surface or space, that space can be made interactive without interfering with the sense of *presence*. Rather than looking at an abstract alternate space in a screen, the data can be added to the real space. Physical pixels can be thought of as 'data throwies' - like the static LED throwies(Figure 2.4) developed by the Graffiti Research Lab[15] , but with the ability to change in response to stimuli (such as interaction or sensor updates. Individual pixels can give an idea of a local reading, but looking at the whole set can give an idea of overall patterns. These kind of displays share similar issues of interpretability as the sonifications and physicalisations however.

Visual displays are not restricted to light emitting displays, or even dynamic displays. Data can be portrayed in a static fashion, using physical materials or more dynamically with kinetic data sculptures. There is an overlap here with tangibles and physicalisations, but the primary difference for our purposes is that these are intended to be consumed primarily or entirely in the visual domain (see (Hogan and Hornecker, 2016) for an interesting discussion of this kind of sensory vs representational modality.) Koeman, Kalnikaité, et al. (2014) argues that mixing low and high tech can be very effective for community displays, with physical, transient displays on alternative surfaces leading to higher community engagement than display screens.

Another interaction paradigm that's typically optical in nature is Augmented Reality (AR). There are several variants of and approaches to AR, but broadly it involves the overlaying of real scenes and real objects with digital augmentations in real time (Azuma, 1997). Traditionally, research and applications of AR used Head Mounted Displays (HMDs) worn by the user, however recently the majority of research has shifted to focus on smartphones and tablets; although there are a small number of studies using senses other than visual, such as those using audio and haptic 'displays' (Dey et al., 2018). Dey et al. (2018) conducted a systemic review of AR research and identified collaboration as one of the categories of AR application (albeit a relatively small one, representing 4% of papers in the review). In line with the general trend of collaborative research

[15] http://www.graffitiresearchlab.com/blog/projects/led-throwies/

discussed previously, the majority of AR collaboration studies focus on *remote* rather than face-to-face collaboration. Although interactivity is core to AR (Azuma, 1997), actually *interacting* in AR is a major challenge for the medium (Ducher, 2014); selecting objects of interest in the world is difficult as the world presented on displays has 'depth' but the display itself only has the *illusion* of depth, particularly problematic in touchscreens when touching the screen blocks the view. Gesturing and interacting with virtual objects in the world space rather than on the screen can overcome these issues, however in this paradigm users struggle with the lack of haptic feedback - there's no object actually 'there' to be grasped (Hürst and Wezel, 2013), and not only are these kinds of 'in air' interactions fatiguing and imprecise (Ens et al., 2018), but also perceived as socially awkward by potential users (Ahlström, Hasan, and Irani, 2014).

Henrysson, Billinghurst, and Ollila (2005) argue that the shift to mobile devices is best served by a different type of device metaphor - using the device itself as a 'lens' on the scene, where the motion and position of the lens itself within the scene is used to interact, rather than what they describe as 'separate' controls. Although Henrysson, Billinghurst, and Ollila (2005) were looking at a a table-sized space, and a limited range of motion of the device within it to *represent* larger motion within the scene, this seems very applicable to a large shared space - by mapping displays directly to the space, users can take advantage of their understanding of exploring a physical space to interrogate the overlaid 'data' space.

One recent consumer application making use of this kind on lens-based interface is Pokémon Go[16]. This game makes use of geolocation for the majority of its gameplay, and uses an AR interface for capturing the eponymous pokémon(Figure 2.5). In a sense, the player's world position is the major way of interacting with the game, both on the coarse geolocation level, and at the finer grained AR level. It should be noted however that, despite recent improvements to the app's AR implementation, the majority of players turn AR off as it interferes with gameplay and is seen as a

[16]https://www.pokemongo.com/en-gb/

Figure 2.4: LED throwies under a bridge in Berlin. From flickr, https://flic.kr/p/9qEqmF, Creative Commons CC BY 2.0 license

'gimmick', despite ostensibly being the game's main selling point[17].

An example of embedding the AR interaction more strongly into the environment is the Magic Mirror (Javornik et al., 2016). The magic mirror approach literally turns the lens paradigm around by augmenting a reflected (or reversed) image of users rather than a view through the display[18]. There are a number of recent commercial applications using this approach for virtual try-on apps, particularly for cosmetics. Javornik et al. (2016) explored the use of such an in-store magic mirror by cosmetics shoppers - the 'mirror' augmented the user's reflection with makeup, as if they were trying it on physically. In-store observations, tracking information from the mirror and survey data showed that the mirror was found not just to

[17]https://www.forbes.com/sites/davidthier/2017/12/21/pokemon-gos-new-ar-on-ios-is-actually-cool-but-needs-work/

[18]It is possible that more radical departures such as third-person AR where you see yourself from behind might have even higher surprise value, possibly at a cost of utility.

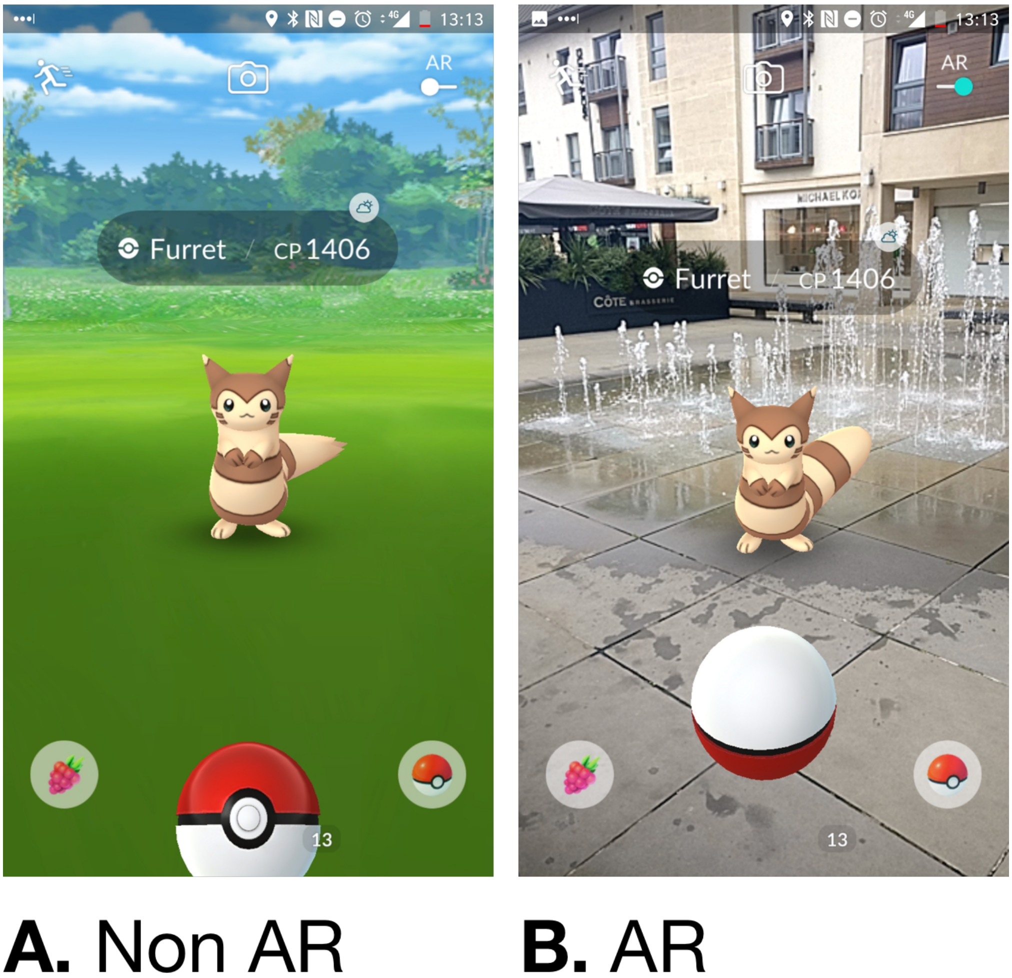

Figure 2.5: A Pokémon Go player attempting to catch a Furret, AR and Non-AR views. When providing these images, the player in question said that she does not use the AR mode as *"...after the novelty of it has worn off, it just doesn't add anything to the game"* (E.I.M Collins, personal communication, 2018)

be playful and engaging, but also useful in making purchase decisions. Javornik et al. (2016) argue that the observed utility makes the mirror more than just a gimmick, however it is unknown if repeated exposure to this kind of AR application would lead to sustained engagement - how much of the playfulness comes from the surprise element that the authors note, and how much from the inherent enjoyment of the interaction? Unlike Pokémon Go, there *is* a utility element separate from the hedonic element, which may mean this specific AR application could see sustained engagement, but it is difficult to tell if magic mirrors *per se* are more adopted than lenses or HMDs. It's possible that magic mirrors may be more similar to public displays than to more traditional AR approaches - for instance, Javornik et al. (2016) identified similar evaluation apprehension effects as discussed earlier in relation to public displays.

AR technology is now reaching the level of maturity where AR can be deployed outdoors and in unstructured contexts, but it is not clear how effective AR is in these wild contexts, beyond the novelty factor - and indeed, such interfaces may even interfere with the task at hand (as in the Pokémon Go example). It does appear that different types of AR interface lead to *surprise* and *enjoyment*, at least on initial use - this might be useful as a way of introducing novel concepts or eliciting responses to technology outside of the framing of everyday digital technology such as smartphones and laptops.

2.3 Research "In The Wild"

This section gives a brief overview of Research In The Wild (RITW), the benefits and challenges, and the importance of technology deployment to RITW. HCI researchers are increasingly interested in what Rogers calls the *everydayness* of life; everyday activities situated in real, messy spaces with multiple inhabitants and visitors (Rogers, 2012). But how do we conduct research in such spaces? Whilst techniques derived from ethnographic practice are useful for examining these ill-structured spaces and understanding current practice, they lack the ability to explore future use (Boehner et al., 2007). Approaches such as probes and breaching trials can be used to go beyond current practice and enable this future exploration (Brown, Reeves, and Sherwood, 2011; Crabtree, 2004) [19]. Cultural Probes, for example, were introduced by Gaver, Dunne, and Pacenti (1999) in 1999, with the goal of exploring potential gaps for technology interventions in unfamiliar communities without wanting to superimpose the researchers' own designs, but at the same time not wanting the communities to constrain their creative designs by focussing too much on their current practice and immediate needs. By disrupting practice and examining behaviour change in this manner, we can help shape research ideas and future designs. An 'in the wild' approach (as described in Rogers (2012)) can use provocation or disruption to practice in order to observe behavioural change.

2.3.1 What is Research In The Wild?

The use of "In The Wild" in HCI arose as a term in the field in the mid–2000s, following late 1980s and early 1990s work by anthropologists on 'cognition in the wild' (Rogers, 2012), a movement which rejected then-current 'cognitive science' approach which focused on the brain as an isolated, symbol processing machine which is ultimately rational within the constraints of that processing machinery (Simon, 1996). Early cognition in the wild writers wanted to take the conceptualisation of cognition out of people's heads, and into the broader world of body, environment and culture. Rogers and Marshall (2017) identify three key foundational texts that represent this 'cognition in the wild' movement: Suchman's *Plans and Situated Actions* (Suchman, 1987), Lave's *Cognition in Practice* (Lave, 1988) and Hutchins's *Cognition in the Wild* (Hutchins, 1995).

In *Plans and Situated Actions*, Suchman (1987) presents the idea that hu-

[19] Although at this point the researcher is no longer investigating the everyday (Brown, Reeves, and Sherwood, 2011) *per se* they are still focused on the everyday context, even while looking at disruptions to the existing practice within that context.

mans are not driven by the rational execution of plans, but rather that their actions emerge from the sum of their lived experience - not just 'internal' cognitive processes, but also the embodied experience of that specific moment. As such, she argues that when investigating human thought and behaviour, it is important to broaden the unit of analysis to include this wider world, observing interactions *in situ*. Lave argues similarly in *Cognition in Practice* that knowledge "in the head" doesn't just *interact* with the world "outside the head" (including body, activity, culture and setting), but that cognition is *stretched out* over all these elements. She further argues that its not possible to separate the 'embodied self' from the 'lived-in world'. This necessitates taking research out of the laboratory, and into the wild (Lave uses the term 'outdoors') using ethnography and what Lave describes as 'simulation experiments' *in situ*. Lave reports a series of studies on arithmetic use in real life situations, observing that participants' 'cognition' was shaped by not just the immediate environment and things in it, but also by their customary practices, previous experience and knowledge about other environments (such as in a study on shoppers, where a participant made selections based on the amount of shelf space in their cupboard, even though they were ostensibly looking for the cheapest price).

Hutchins (1995) argued that cognitive science had "disembodied cognition" by separating cognitive, computational processes from the sensorimotor experiences of the body. Hutchins posits this came about due to a focus on laboratory experiments (which he described as 'captive cognition') and the misuse of the computer as a model for human cognition[20], leading to modelling of 'cognitive' processes within an individual as totally divorced from their own body, senses and the wider environment and culture. Hutchins argues that in reacting against the previously prevailing paradigm of behaviourism (broadly, that only externally observable behaviour was important), cognitivism swung too far in the other direction

[20] It's possible that the computer had another, reinforcing effect; Simon (1996) discusses not only the computer as a model for the mind, but also how computers *enable* the modelling of cognitive processes.

in focussing *only* on the internal mind/brain, reducing external interaction to the kind of modular input-output suggested by the brain-as-a-computer model. Hutchins suggested that the way to move forward from the cognitive science model was to "re-embody cognition"; to examine the way people thought and behaved *in situ* rather than in the lab.

As cognition in the wild went from a contrarian to a mainstream position over time, the use of "In the wild" in HCI has evolved from being broadly used to indicate an *in situ* or *contextual* study which follows these Cognition in The Wild precepts of embodied and distributed cognition over more classical lab-based experiments (often with a focus on evaluating systems as seen in Rogers, Connelly, et al. (2007)), to a philosophy of approaching research. Cognition in the Wild was interested in *understanding* existing practice, whereas the core differentiator of modern Research In The Wild (RITW) over other ethnographic approaches is that rather than focussing on *existing* practice or requirements gathering, 'novel technologies are developed to augment people, places and settings; interventions installed and different ways of behaving encouraged.' (Rogers and Marshall, 2017). Instead of approaching design as a process of observing practice and incrementally optimising designs to fit in with these practices (as in User Centred Design), RITW aims to alter behaviours more radically through the introduction of novel designs and technologies (Rogers and Marshall, 2017). This is part of a broader shift in design thinking(*ibid*) that acknowledges the inherent subjectivity in research, further moving away from the strict positivism that authors such as Lave and Hutchins felt had led cognitivism astray. Another defining characteristic of RITW is that RITW projects typically involve multiple linked threads in parallel, such as technology development, use and development of methods and theory, and in-situ studies. Rather than focus on separate aspects, the RITW project treats these parts of the research as interdependent (Rogers and Marshall, 2017).

Rogers and Marshall present the first and at time of writing, the only (Y. Rogers, personal communication, November 2018) framework (Rogers and Marshall, 2017) for understanding RITW projects, consisting of four inter-related ‘core bases’: Theory, In-Situ, Design and Technology (see Figure 2.6). These core bases are intended to be inter-related and cross-fertilising, and the framework is intentionally non-prescriptive about what order to approach these core bases in. RITW is broad in scope and ‘agnostic about the methods, technologies or theories it uses’ (Rogers and Marshall, 2017); one constant however, is that RITW involves not just observation but active alteration through introduction of technology.

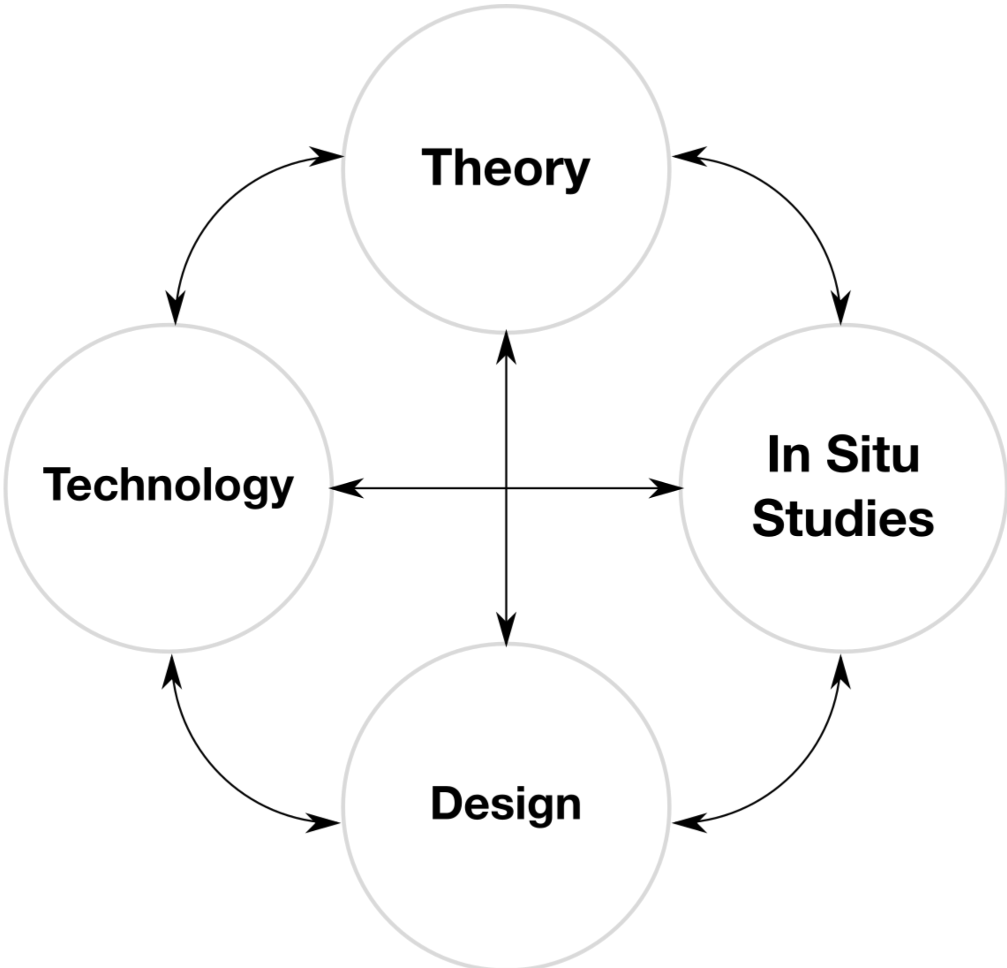

Figure 2.6: RITW framework from Rogers and Marshall (2017). Adapted from figure on p.6 of *Research in The Wild*.

2.3.2 Challenges for Research In The Wild

RITW can be time consuming and expensive (Rogers and Marshall, 2017), and the interconnected nature of the research project can make it more difficult to cleanly isolate 'research products' for publication, and it has been argued that these costs can be avoided and the benefits of RITW can be achieved in a lab setting (Kjeldskov, Skov, et al., 2004).

Kjeldskov, Skov, et al. (2004) discuss a simulationist approach to doing 'fieldwork'; effectively, creating a context in the lab that models some of the aspects of the real world context, and conducting trials there. They argue that this approach actually captured *more* usability issues than 'in the wild' trials in the field. However, while a simulationist approach can be useful as a means of investigating behaviour, it is not suitable for capturing *real world* behaviours - and indeed, this is seen in the Kjeldskov, Skov, et al. (2004) paper in their own examples[21]. The exemplar for 'issues spotted in the lab but not the wild' was the use of an input modality that was *never used in the wild*; and the example of an 'issue spotted in the wild but not the lab' was an important trust issue, suggesting that in fact the simulated environment captured irrelevant usability issues and missed vital contextual ones. Additionally, this narrow focus on 'usability' appears to run counter to the goals of RITW.

There are also a number of studies demonstrating different findings in the wild when compared to lab settings (Rogers and Marshall, 2017). Marshall, Morris, et al. (2011) for example saw vastly different behaviour using a multitouch table *in situ* than in the lab, uncovering a central assumption (that people would use the device together as a group, rather than concurrently as individuals) that did not hold in a real world setting. Indeed, different wild contexts can lead to different responses for the same deployment (Gallacher et al., 2015).

It's possible to argue that this very sensitivity to context leads to chal-

[21] This does not preclude lab studies from having a place within a RITW process, and indeed this thesis argues that lab studies can be a valuable tool - see chapter 6.

lenges of robustness, objectivity and inference; however Brown, Reeves, and Sherwood (2011) argue that *“the very inspiration for research ‘in the wild’ is abandoning notions of purity or simple deterministic relationships between technology and use.”* (Brown, Reeves, and Sherwood, 2011). More problematic for RITW in use is its lack of prescription. RITW’s broad scope and agnostic attitude to methods, technologies and theories makes RITW highly adaptable to different research contexts, but also leads to a myriad of decisions to make and parameters to tweak, the approach to which will vary wildly depending on the context and motivations of the research).

Whether custom-designed or off-the shelf, the design and selection of the intervention in RITW is a vital part of the method (Rogers and Marshall, 2017). However researchers often do not make this part of their reasoning explicit and there is as yet little research into how best to approach this aspect of RITW. Unlike the positivist scientific paradigm, where there is a protocol in place to describe the procedure behind an experiment and the thinking underlying hypothesis generation, it is less clear what the research thinking is when researchers decide on how to create a technological intervention. So how do researchers decide how to create a technological intervention?

2.3.3 Which technology?

Designers and researchers have access to a huge array of technologies and interfaces; Preece, Sharp, and Rogers (2015) catalogue 20 of the more prevalent types of interface that have been developed and used over the last 10–30 years, and this is by no means an exhaustive list. It is possible and affordable to choose almost anything from this buffet of technologies, from the more mundane tech such as web and mobile (Heyer and Brereton, 2010), to more ‘exotic’ ones, such as tangibles (Golsteijn et al., 2015; Houben, Golsteijn, et al., 2016) and robots (Sabanovic, Michalowski, and Simmons, 2006; Kuznetsov, Paulos, et al., 2010). So how should researchers select a technology? There are various motivations for the research and its grounding that need to be taken into account, such as community driven, contemporary social commentary, theory, and technology driven motivations (Rogers, 2012). These framings will suggest constraints, such as cost, user acceptance, usability, potential impact on behaviour and level of user involvement. For example, a design could be constructed purely based on the social commentary and alternative theory aspects, making use of design guidelines and frameworks to support a principled approach. However, in order to contextualise this design we need to know more about the target area. In some cases, this context could be driven by a community request (as in Golsteijn et al. (2015)), but despite being an ideal case for community engagement (Balestrini, Bird, et al., 2014), this kind of participant driven motivation is not always feasible in a research setting (*ibid*). Balestrini, Bird, et al. (2014) used a collection of 'off the shelf' technologies - mobile phones, YouTube, QR codes and Google maps. These 'locally available everyday technologies' were used in a community history project to maintain engagement and sustainability, and to encourage uptake through familiarity and ownership. The project also reported practical advantages to using existing tools, arguing that they support sustainability of the project, as the ongoing maintenance of the technology deployed does not require researcher intervention. Although Balestrini, Bird, et al. (2014) report on widespread successful community engagement and broader impact, their research outputs focus primarily on how to design for community engagement. Whilst such community driven initiatives often capture contemporary matters of concern, (or what Rogers (2012) calls contemporary social commentary)) by their nature, it is also possible for these contemporary social issues to take centre stage; for instance, Kuznetsov and Paulos (2010) used mock sensors to investigate 'activating spaces', driven entirely by political concerns. This use of mocked-up sensors (actually colourful cardboard boxes) demonstrates that the technology in question does not have to be functional to be useful as a probe. The selection of 'low tech' materials can also be driven by community concerns. Koeman, Kalnikaité, et al. (2014), for example, used chalk graffiti for representing voting data, to avoid screen aversion in public displays and to make it widely accessible to the general public. The voting data was collected with physical voting boxes, highlighting that deployments do not necessarily consist of a single type of technology or interface. A provocation could also be inspired by the general concept of a technology, introducing it to everyday contexts where it doesn't yet exist. For example, Kuznetsov, Paulos, et al. (2010) introduced wall crawling robots to public spaces, in essence, to see what would happen. This kind of 'designerly curiosity' is as legitimate a driver as any other (Raptis et al., 2017). Alternatively, the provocation could be more heavily driven by a specific technology or product; by introducing a novel technology into its intended context (such as in (Wang et al., 2017)), or an existing technology to novel or unintended contexts. These motivations for introducing prototypes into a community setting are not orthogonal; the different motivations and concerns will co-develop and cross-fertilise in a RITW project (Rogers and Marshall, 2017).

2.3.4 Which Methodology?

RITW is not just *one study* it is a *process*. Any research project involves a slew of decisions, from big headline choices such as method and theoretical framing, down to the minutiae of operational detail, and RITW is no exception. As researchers, we often neglect to document and reflect on these decisions and their impact on our research and our thinking (Braun and Clarke, 2006). This is not limited to HCI, but is true even of the 'hardest' of sciences (Mitroff, 1976).

Researchers need to make these decisions explicit, by engaging in what Braun and Clarke (2006) call *"an ongoing reflexive dialogue on the part of the researcher or researchers"*. In other words, rather than presenting their research as a *fait accompli*, researchers should engage more fully in dialogue with consumers of their work with regards to how they got to where they were going, and despite the broad umbrella of RITW it is no exception. Indeed, it could be argued that it is of *more* importance within RITW to justify methods and approaches, since there is such a broad scope of possibilities to choose from.

Mixed methods are common in HCI for many different reasons including triangulation, and commonly as the use of multiple methods helps to establish legitimacy and credibility (Bryman, 2006). RITW tends towards ethnographically derived methods; the deployment itself involves the investigation of a real context, and it makes sense that ethnographic techniques are often seen as an appropriate match for investigating these contexts. However, it is also possible to think more broadly about methods for RITW: Brown, Reeves, and Sherwood (2011) argue that researchers often make the assumption that trials have to be as 'natural' as possible, but that more innovation in methodology can lead to a greater range and scope of findings. This attitude is in contrast to those such as Kjeldskov, Skov, et al. (2004), who see the point as trying to simulate a natural environment as closely as possible. (Although Kjeldskov's stance evolved over the years, later agreeing with Rogers that the focus on usability evaluation that led to this kind of simulationism is flawed (Kjeldskov and Skov, 2014)) A variety of methods can be used in RITW not just to investigate the context and to evaluate systems (especially in early views of RITW), but also for *constraining the design space.* Although it is possible for a RITW project to be driven by or inspired by the use of a particular type of method, more commonly the selection of the methods is motivated by the goal of the project arising from design, context or theoretical concerns. Again, many or all of these methodological concerns are not unique to or limited to RITW, and are more broadly applicable, even outside of HCI. RITW's non-prescriptive nature when it comes to method however means that there is not necessarily a 'default' choice of methods and approaches.

Whilst some HCI approaches are criticised for being pragmatic and atheoretical (e.g. (Kaptelinin and Nardi, 2006) on Distributed Cognition), despite its pragmatism RITW explicitly includes theory (both as a driving force and as an output). In order to constrain design space, we can use theory and conceptual tools. We can also consider appropriate theories in order both to understand findings and to motivate methodology. In this manner, theory wends its way throughout the different aspects of RITW, despite its pragmatic and eclectic approach.

2.3.5 Which theory?

So which theories should RITW practitioners select? This will depend on the motivation - in the same way as some research being driven by novel technology or design curiosity, research may have theory as the driver. This maps onto more traditional HCI and experimental psychology approaches where the research serves to elucidate the theory, rather than theory being in service to a more immediately practical end. Theory in RITW can be a major driver of the research, as in Yuill and Martin (2016), who "drew heavily from developmental theory" (Rogers and Marshall, 2017) both for motivation and for experimental design. However, the parallel co-construction of RITW from the 4 core bases mean that theory doesn't have to come first in RITW, or even be a major driver of the research. It can also be used in the selection and development of methods and design; for instance, Raptis et al. (2017) use critical theory and theories of 'provocativeness' in their design of prototypes for deployment into the wild. In many ways, this is no different to other research approaches: the main difference is that RITW makes it *explicit* that theory is intertwined with the research process in different ways throughout.

There is also the *development* of *wild theory* to be considered (Rogers, 2012) - RITW projects do not just use theory, they can lead to the *development* of theory. As with other aspects of RITW, the non-linear and interconnected nature of the framework allows these co-developments - although this can make it difficult to structure into a linear chronological narrative, arguably *all* but the simplest research is like this; presenting and publishing research is highly stylised and ritualised (Feyerabend, 1993), which hides these aspects that RITW makes explicitly a part of the framework.

2.4 Conclusion

Sensor and data solutions can support decision making and improve the chances of viability in community plant growing (Campbell, 2013; Lyle, 2013), however there is as yet little HCI work in this area (Hirsch, 2014; Odom, 2014), and it has been argued that 'technological rejection' by community gardeners makes this an unsuitable area for further study(*ibid*). However, it is the disconnect with the natural world induced by current dominant design paradigms (Bidwell and Browning, 2010; Robinson, Marsden, and M. Jones, 2014) that is rejected, not technology in and of itself (Goodman and Rosner, 2011). As such, we argue that a useful contribution to knowledge can be made by exploring this gap in the literature, rather than considering it a dead end for HCI investigation - both in terms of the practical outcome of supporting design for this context, but also of providing an indication that there *is* potential in this area for future research.

Rejection appears to arise from gardeners beliefs that automation and the reduction of agency (Goodman and Rosner, 2011) will interfere with their relationship with the garden and with other members of the community (Odom, 2014). There is a repeating theme in both industry and academia of focussing on individuals (Sengers et al., 2004; Sellen et al., 2009; Klokmose and Zander, 2010; Lundgren et al., 2015) and where collaboration is supported it is via *artificial proximity* (Mejia, Morán, and Favela, 2007). This paradigm leads to the disconnect with reality (Robinson, Marsden, and M. Jones, 2014) that gardeners are averse to. Therefore, if we want to investigate how to provide sensor and data tools without interfering with gardeners' connection to the shared space of the garden we can focus on the collocated, collaborative aspects that current technology neglects (Klokmose and Zander, 2010). Whilst there is much HCI research on collocated collaboration (Rogers, W. Hazlewood, et al., 2004; Lundgren et al., 2015), there is a gap in the literature concerning collaboration in shared spaces; Collocated collaboration research often focuses on colocated, co-temporal groups approaching a task together at the same time, but in real shared spaces such as community gardens, the interactions are asymmetric and spread out over time (Marshall, Morris, et al., 2011).

Research In The Wild offers a possible method for investigating both data in community gardens and shared spaces in parallel, being suited both to unstructured 'everyday' environments (Rogers, 2012) and also to the parallel co-construction of different aspects of the research (Rogers and Marshall, 2017). But how should we constrain the design space for a RITW deployment? The Rogers and Marshall (2017) RITW framework is descriptive rather than normative, and despite discussing the importance of selection and design of technology in a RITW project, does not detail how this should be approached. Reflecting on the use of the RITW framework to guide research, and in particular on how to make these decisions, is useful not only in helping to structure this research but also to provide a case study of the use of the framework.

The objective of this research is therefore to investigate the three gaps identified in this chapter (corresponding to each of the three RQ's, respectively): 1. Explore community gardens as shared spaces, and the tension between desire for connection to the space on one hand and the introduction of sensor and data technology on the other. Are there ways that we can we design to provide the latter whilst supporting the former? 2. Explore colocated collaboration within shared spaces; are there aspects of sensor and data systems within shared spaces such as the garden that have implications for interactive technology? 3. Reflect on the use of the RITW framework as a means of guiding and framing this work.

In order to achieve these aims, we use a variety of methods to examine the *existing context* and *provoke a response* to novel technologies.

3 Methodology

This thesis aims to explore sensing and data technologies for communities or settings where there is initial resistance to technology. In order to achieve this, it is important not just to understand existing practice and context, but also to probe into the effects of not-yet-existing technology on future practice. It is also important to investigate how novel technologies could be applied to future practice. This is because there are two aspects to the tension in community gardens - the aversion aspect and the potential benefit aspect. We are interested not just in reducing the aversion side of this equation - 'how do we overcome resistance?', but also augmenting the benefit side: 'how do we make something valuable and useful that people *want* to use?'.

The overall approach of this research is to apply the RITW framework to a project, pursuing research activities using the framework and reflecting on the process. Four main studies were performed as part of this approach: initial contextual interviews investigating context and covering the *In Situ* core base from the Rogers and Marshall (2017) framework, a co-design workshop covering the *Design* and *Technology* core bases, an experiment covering the *Theory* core base, and a provocative prototype which has elements of all four core bases, informed by the previous studies. Although Rogers and Marshall (2017) show the core bases as interrelated, in practice there is often a progression over time, with earlier studies feeding into later studies. The progression of research presented in this thesis could be thought of as having two interconnected branches, one rooted in context and one in theory, that come together in the provocative prototype as shown in Figure 3.1. Alternatively, we can frame the process as each activity contributing to an emerging theory (Rogers (2012) describes this kind of emergent theory as as a 'wild theory') that can be used to design the final RITW deployment. (see Figure 8.4). The former, chronological framing gives a clearer description of the flow of this specific piece of research, but the latter framing could be applied to any RITW project.

1. **Contextual interviews**

   We performed interviews at 5 different community gardening sites, in order to investigate current practices and attitudes to technology. An exploratory approach was adopted to examine the different communities, to identify similarities and differences between them, and to direct further research.

2. **Co-design workshop**

   Following the interviews, we conducted a co-design workshop with community gardeners to probe responses to novel technologies in the domain.

3. **Situated versus Overview Data Experiment**

   The findings from the interviews and workshop suggested an interesting avenue for exploration, that of *situated* and *overview* informational tools; this experiment was conducted to investigate this further.

4. **Provocative Prototype**

   Finally, we conducted an investigation with one community garden about the adoption and use of novel technology, using provocative prototypes based on the situated/overview representations.

This thesis also contains design elements in support of the research goals[1] in the co-design workshop, experiment and (most prominently) in the provocative prototype; the methodologies and rationales for these design elements are discussed in the chapter of their associated research activity.

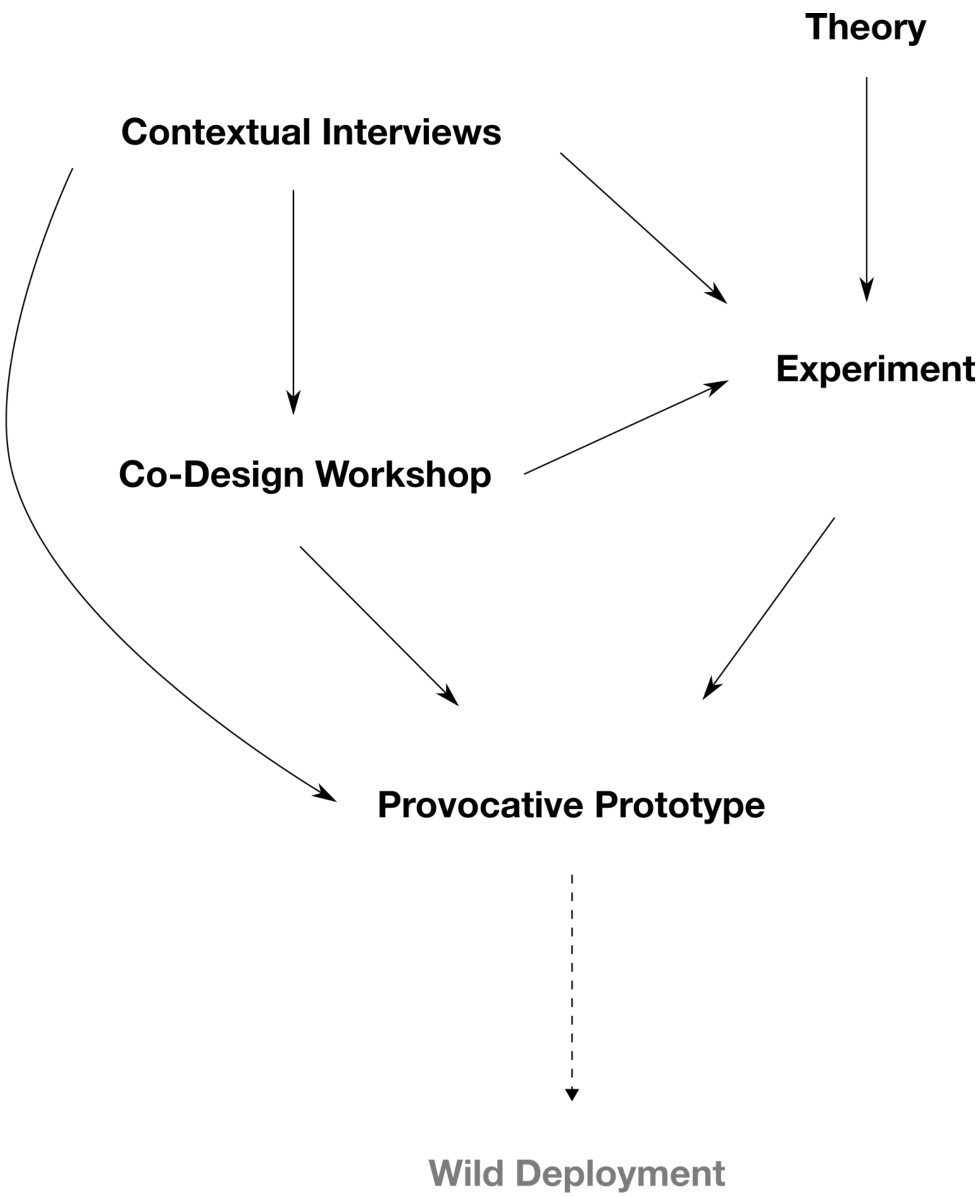

Figure 3.1: This figure show the relationship between the different studies. All of the activities fed into the Provocative Prototype study.

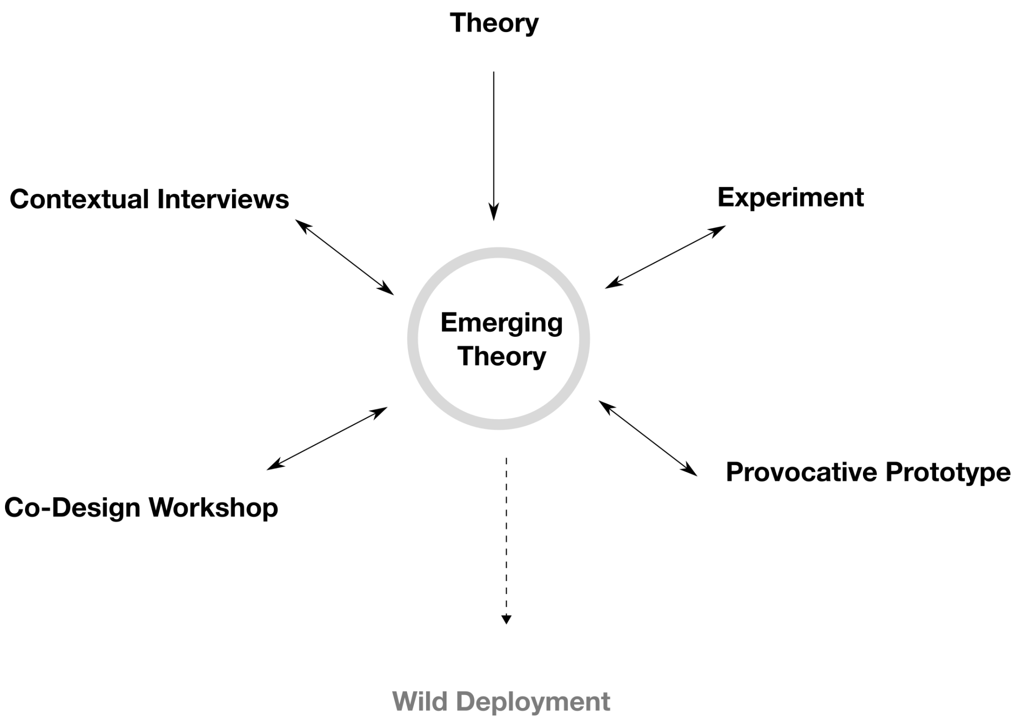

Figure 3.2: An alternative way of conceptualising the research is that each activity feeds into an emerging theory, the evolution of which drives new activities, until the emerging theory reaches a point where a deployment can be made.

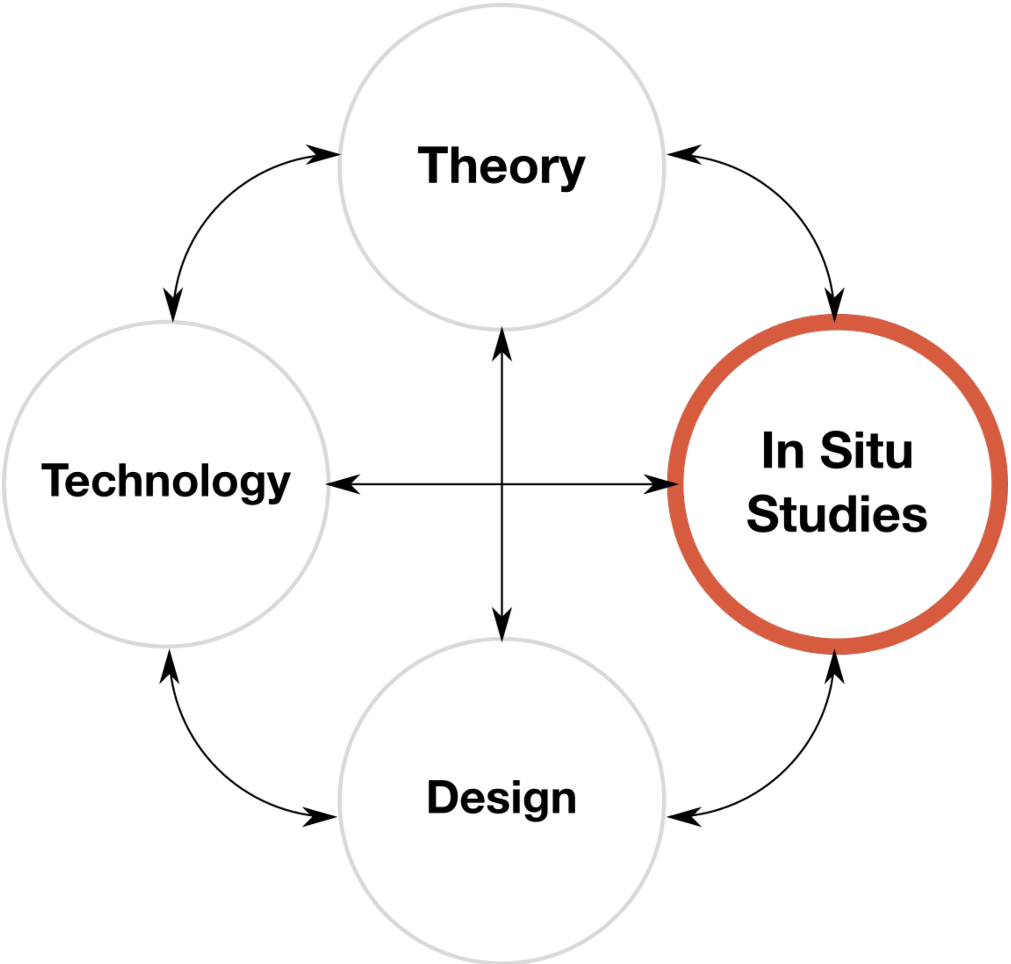

Figure 3.3: The interviews fall into the **In Situ** core base of the RITW framework. We chose this as a starting point in order to better understand the domain.

3.1 Contextual interviews

In Situ Studies were selected as an entry point into the RITW framework, with the intent of establishing existing context and practice in order to begin answering all three of the Research Questions. Examining existing practice in community gardens helps us to understand both the specific context of interest (RQ1) and action in shared spaces more generally (RQ2), and the very act of performing research within the RITW framework provides us with the material to reflect on RQ3. To begin addressing this *context and practice* aspect of the research, several contextual interviews were performed in different community food growing groups in and around London, aiming to investigate current practices, goals, and technology use. This sampling of a variety of groups was intended to gain a broad understanding of the area, highlight similarities and differences between the groups, and also to help focus the problem space and select interesting avenues for further study. These will be described in the next chapter in more detail.

In order to better understand the practices of these groups, a modified grounded theory (Glaser and Strauss, 1967; Strauss and Corbin, 1990) approach was adopted for data collection and analysis. This enabled the discovery of themes without requiring a prior hypothesis (Cairns and Cox, 2008), and also allowed the investigation of complex phenomena which are socially based (Strauss and Corbin, 1990). There are many variants of grounded theory, each with different philosophical underpinnings. As this research is not focused on the philosophical or theoretical development of grounded theory, this phase of the research was based on M. J. Muller and Kogan (2010)'s synthesis of constructivist (Charmaz, 2006), Straussian (Strauss and Corbin, 1990), and Glaserian (Glaser and Strauss, 1967), flavours of grounded theory, which pragmatically focuses on commonalities and utility rather than epistemology (M. J. Muller and Kogan, 2010).

[1] Although in practice it could be argued that this distinction between research and design and relegation for design to a support role is somewhat arbitrary, and indeed in this case the research *as a whole* ended up in many ways a *design lifecycle* prototype - this is considered in the discussion chapter, chapter 8

Following "the usual grounded theory practice" (Haywood and Cairns, 2006), the collection and analysis of data was interwoven, allowing the structure and direction of the semi-structured interviews to be adapted over time and permitting theoretical sampling (the selection of participants to refine the emergent themes (M. J. Muller and Kogan, 2010)). This interweaving of analysis with collection meant that after each session, the researcher could alter the structure and focus of the study in order to probe interesting areas more deeply, or to investigate areas where the emerging themes were vague, poorly supported or contradictory (see Figure 3.4). The theoretical sampling meant that the selection of sites could also be driven by the currents of the research; in this case leading to forest gardens as a particular area of focus[2].

The interviews showed a strong focus on learning within the environment, with community members valuing "learning by doing" and "getting close to the soil", and decisions being made in situ and in an ad-hoc manner. Automation was disliked as it was felt it would disrupt relationships with the space and with other community members. Existing tool use and management items (such as plant information markers) were observed, along with tool archetypes and materials reuse.

Presence in the garden was a core theme identified throughout, underpinning decision making, learning and teaching and the nature of data tools; the physicality of the space and the importance of being embedded within it was threaded through all of the themes.

3.2 Co-Design Workshop

In order to investigate community gardeners' responses to novel technologies and representations, and how these technologies could be designed for the garden context, we needed to introduce gardeners to possible future

[2]These two aspects - the iterative development of the study itself and the ongoing selection of participants were some of the most useful elements of grounded theory approaches to this research - this reflection and implications for wild methods are elaborated in the discussion (chapter 8).

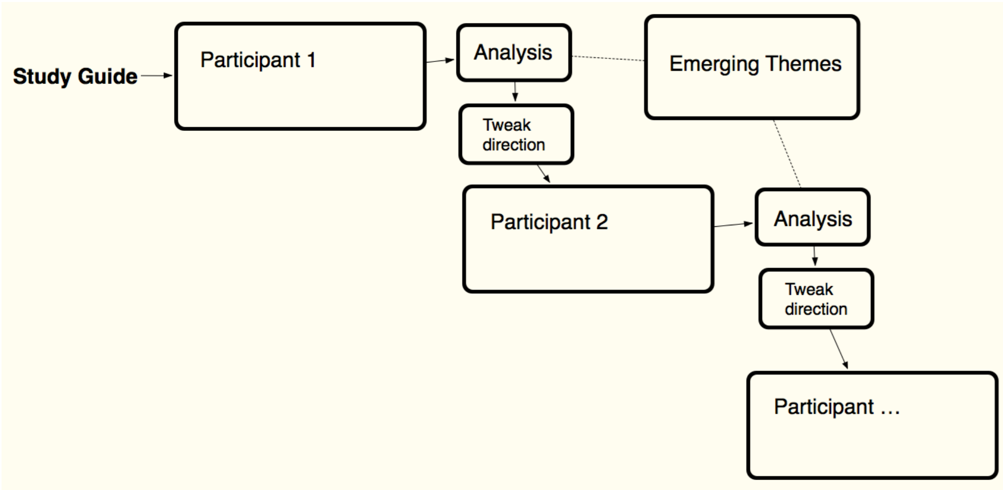

Figure 3.4: The interweaving of data collection and analysis in the modified grounded theory approach used in this research. After each participant, data from the session is analysed and the direction of the research modified and focused. As the research progresses, the existing corpus of analysis is reevaluated in light of new findings, with some categories emerging, merging and solidifying and some collapsing.

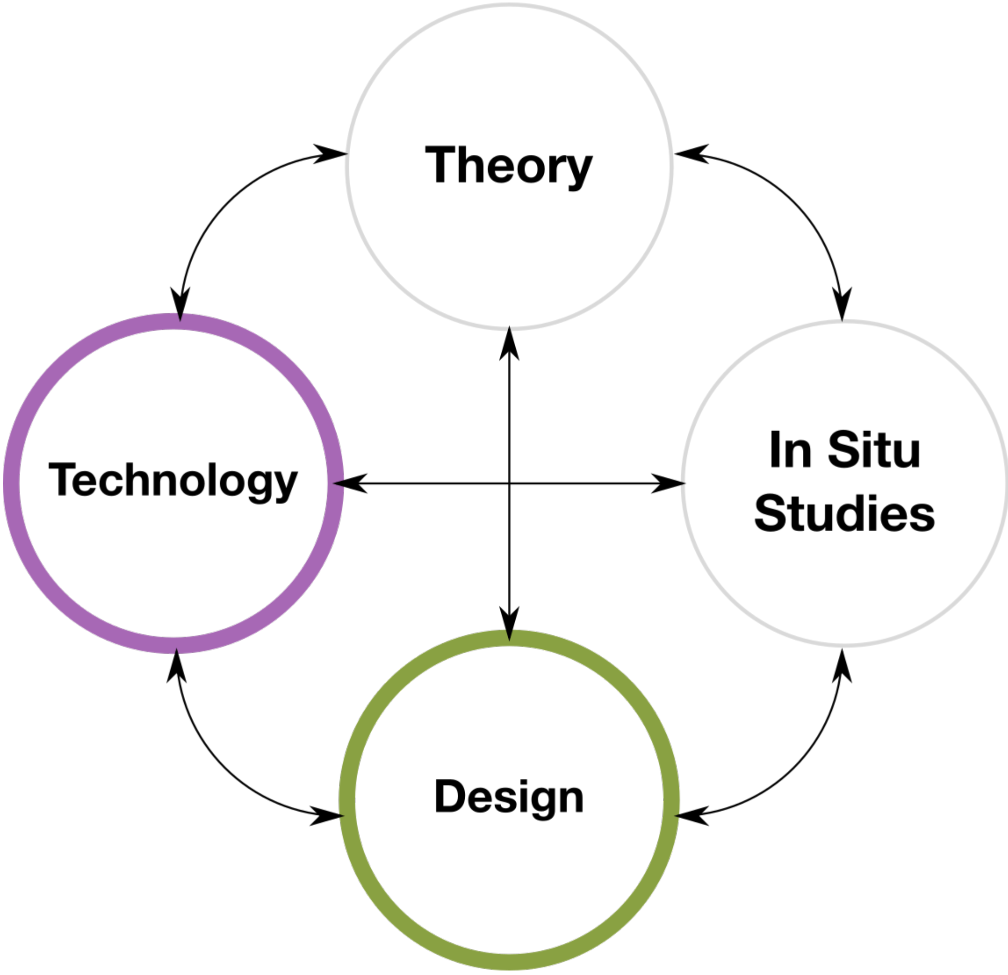

Figure 3.5: The workshop falls into the Technology and Design core bases - the goal was to introduce community gardeners to novel technology, in order to investigate their responses to the technology and how this technology could be designed for a garden context.

technologies. This phase of the research explored the *Technology* and *Design* parts of the RITW framework (Figure 3.5); This phase of the research was primarily intended to address RQ1; both the process of selecting methods and technology for the workshop, and the way in which the outputs of the workshop impact the selection of technology and design inform how we can use the RITW framework to choose particular technologies and specific designs. The findings from the workshop were also intended to further develop understanding of gardening practice and potential future practice in order to address RQ1 with specific design for the garden.

A co-design workshop was thus planned with the aim of enabling informed speculation (DiSalvo, Lukens, et al., 2014) by community members, in order to elicit values and needs in relation to sensors and data in the garden, and further investigate findings from the previous contextual interviews.

The workshop was designed using a *learn, discover, invent* stucture (DiSalvo, Lukens, et al., 2014), to scaffold knowledge and awareness of the capabilities of sensing technology and the possibilities of novel interactions in the garden. In contrast to the previous study that used grounded theory, thematic analysis was used as it is flexible, lightweight and particularly suited to participatory design (Braun and Clarke, 2006). The aim of the workshop was focused less towards initial discovery and theory generation, and more directed to specific themes. Coding was performed on notes and observations from the session notes of the facilitator and supporting researchers, post session notes and design artefacts (sketches and physical prototypes produced by participants). The 'keyness' of themes (which themes were most interesting/important/relevant), was determined by a mix of prevalence and apparent relevance to our research questions (Cairns and Cox, 2008).

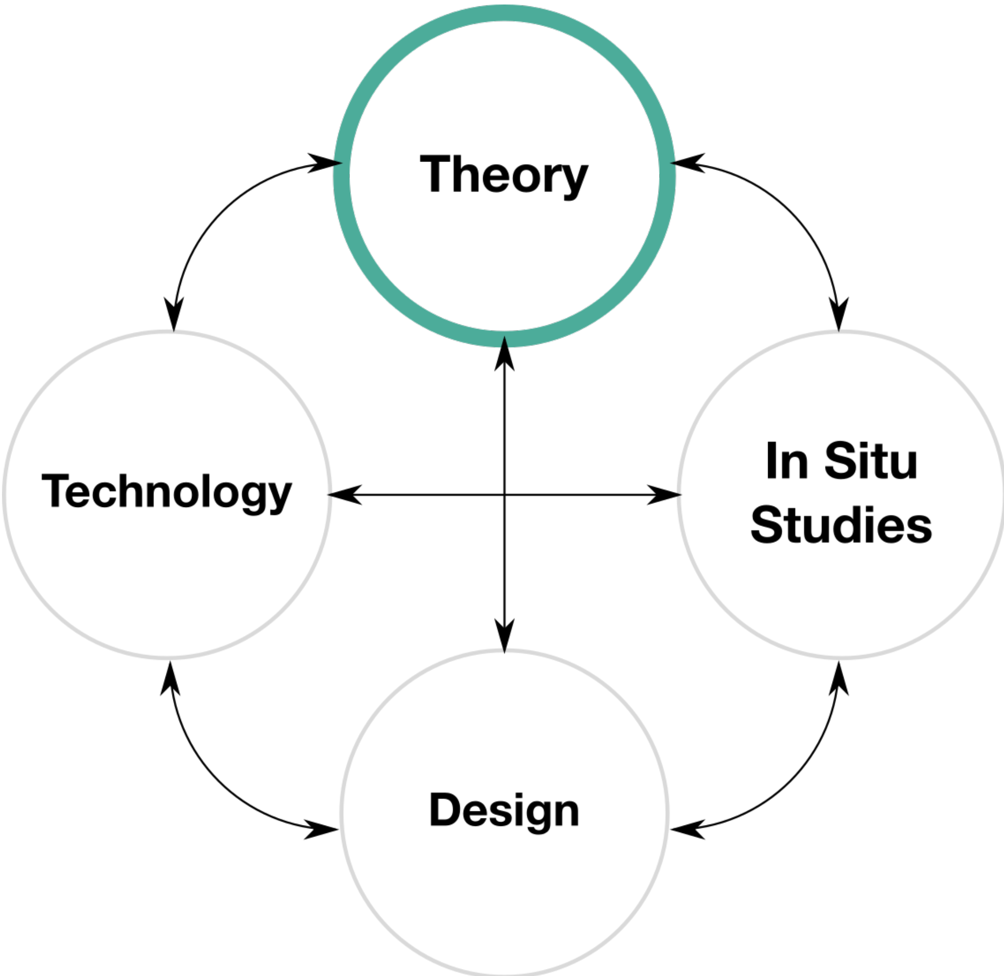

Figure 3.6: The experiment didn't give insight into the garden context, but rather helped to contribute to *theory* about overview vs situated information, which helped inform our design of the Provocative Prototype

3.3 Situated versus Overview Data Experiment

The third phase of the research was designed to probe more deeply into theoretical aspects of the 'situatedness' of data uncovered in the first two phases. It addressed RQ2 by examining the effects of different types of data on behaviour in shared spaces, and RQ3 by exploring if lab experiments could be used as part of the RITW framework.

Both the Contextual Interviews and Co-Design workshop had highlighted an interesting tension around 'situated' and 'overview' data, but what does this mean? Before committing to a prototype and deployment at this stage, it was useful to step back from the wild and consider another way of approaching the problem space (Figure 3.6). A lab experiment was performed, not as a means for divining truth about the context of the domain of interest by emulating it (in contrast with simulationist approaches such as (Kjeldskov, Skov, et al., 2004)), but as a way of isolating a particular aspect of interest and reframing the problem space in order to inform our perspective: setting up an experiment requires operationalising the problem space and reasoning about the outputs, adding nuance to our understanding of the effects of situated and overview data.

The usage of prototypes in a lab setting and in the wild differs, and lab experiments can't capture real world use (Rogers and Marshall, 2017). However, we can use controlled experiments to examine aspects of human behaviour that may be of interest to us in designing for the wild. In terms of the RITW framework, experiments can contribute to the *Theory* aspect of the framework - **not** the *in situ* aspect. This is discussed more in depth in both the experiment's own chapter (chapter 6) and in the discussion (chapter 8).

A room-scale collocated collaborative task was designed to investigate the effects of providing "situated" and "overview" data in an abstract setting, and to investigate the effects this data has on performance and behaviour in collocated collaboration in shared spaces. A mixed approach was used in the analysis of the data, combining both statistical modelling approaches to examine behaviour over time and qualitative analysis of recordings and observations of behaviour. A Linear Mixed Effects Model comparison approach was used to examine the effects of situated and overview information on behaviour, as it allows both the change due to the experimental treatment and the temporal element to be addressed (Singer and J. B. Willett, 2003). Whilst the aim of the statistical analysis was to determine whether situated or overview data would lead to improved performance (informing RQ2 and to a lesser extent RQ1), the shift in perspective involved in designing and operationalising parameters to test and analyse in an experiment was valuable in addressing RQ3.

The following study was designed to investigate these different types of data and their effects on behaviour in a real world context, specifically in a community garden.

3.4 Provocative Prototypes for community gardens

For the final phase of the research, provocative prototypes were developed and deployed into a community forest garden in order to elicit responses to the different types of situated data explored in the experiment - specifically Situated (augmented reality) and Overview (map) representations of light level data. The aim was to address all three research questions: the use and design of provocative prototypes within RITW aims to help answer RQ3, the further development of situated/overview data concepts and their applicability to action in shared spaces in context addresses RQ2, and findings from the study specific to the community garden context help in answering RQ1.

From the contextual interviews and workshop, we saw that community gardeners describe making decisions *in situ* and *in the moment*, but also that there are additional 'overview' tools in real and imagined systems. The experimental study suggested that these different types of representa-

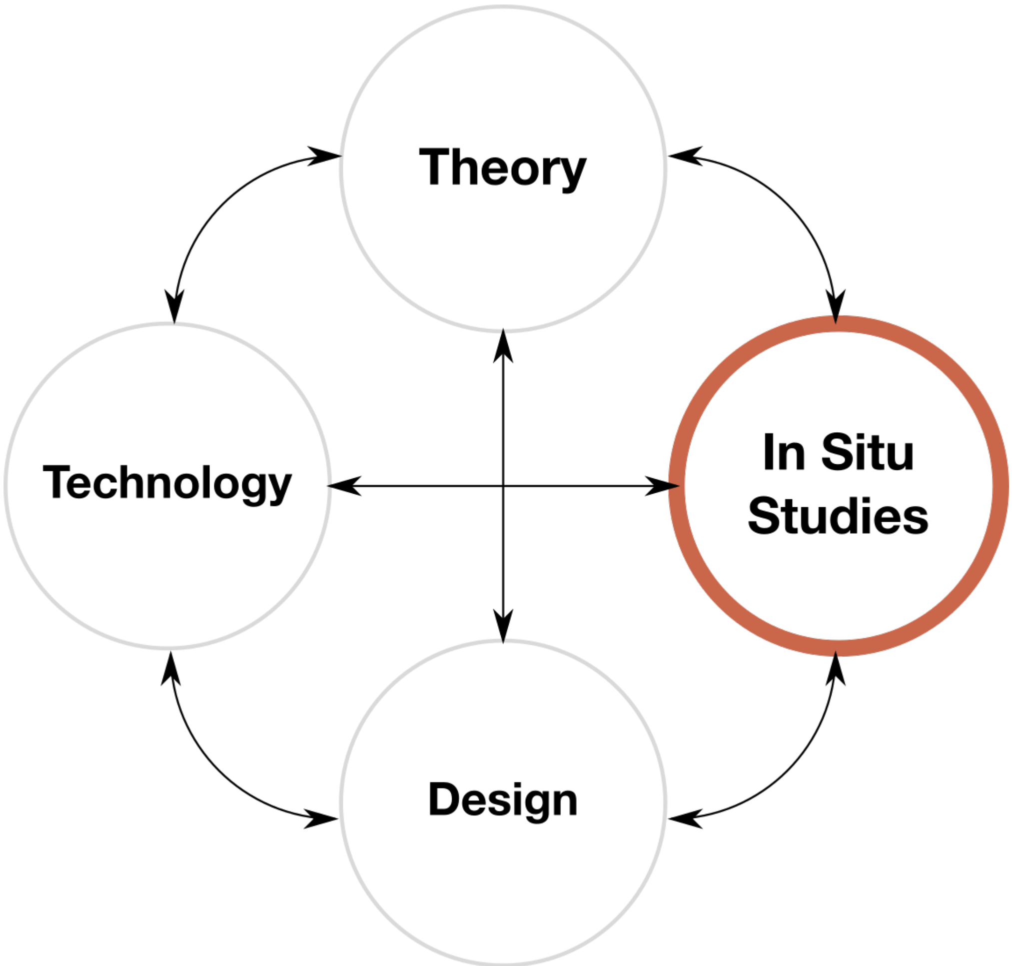

Figure 3.7: Here we return to the in-situ core base; taking the outputs from the first three studies back into the field.

tion may support action in different ways, and also that there is an aspect to decision making in the garden that is additional to the 'ad hoc' decisions described by gardeners, but which we have not observed. As such, we wanted to further explore situated and overview representations in context, and elicit references to usage of these unseen aspects (Figure 3.7).

We define a *provocative prototype* as being one of a class of artefacts that Heyer and Brereton (2008) describe as *exploratory prototypes. Exploratory prototypes* are research artefacts that are inspired by (and often described by authors as) technology probes (Hutchinson et al., 2003), but which diverge from Hutchinson et al's 'original formulation' (Heyer and Brereton, 2008), and which are useful for investigating the properties of a system which is beyond existing practice. Heyer and Brereton (2008) and Redhead and Brereton (2009), argue that such prototypes are particularly suited to encouraging community participation in situations where research is not originally motivated by community members (a common occurrence in HCI due to the application of novel interactions or new applications of technology (Balestrini, Bird, et al., 2014)). We call this a *provocative* prototype as it is weighted towards exploring aspects of sensing and action in the garden rather than designing a solution for this specific community garden[3].

Whilst ethnographic methods imported into HCI are excellent for analysing and describing *current* situations, they lack the ability to 'proffer suggestions of a possible future' (Heyer and Brereton, 2010). As such, HCI has developed from initial imported methods a wide range of 'probe' methods to explore these possible futures (Boehner et al., 2007). Cultural Probes were introduced to the field by Gaver et al in 1999, with the goal of addressing:

> ...a common dilemma in developing projects for unfamiliar groups.

[3] (Boehner et al., 2007) argue that this provocative element was originally the most important aspect of probes generally in HCI, but that this has been lost sight of by many in the field; it thus becomes important to re-emphasise this provocative nature rather than taking its assumption for granted.

> Understanding the local cultures was necessary so that our designs wouldn't seem irrelevant or arrogant, but we didn't want the groups to constrain our designs unduly by focusing on needs or desires they already understood. (Gaver, Dunne, and Pacenti, 1999)

There has been much adoption and adaption in the field since, with the proliferation of many variants (Boehner et al., 2007) of which *Technology probes* are arguably the most influential (Boehner et al., 2007). Hutchinson et al. (2003) originally defined technology probes as being open ended, longitudinal and self logging, however the method has been adapted and extended over time and many technology probes in the literature do not hew to this initial definition (Heyer and Brereton, 2008). According to Hutchinson et al. (2003), technology probes are "…not a prototype, but a tool to help determine which kinds of technologies would be interesting to design in the future", however Heyer and Brereton (2008) argue that the broader body of techniques that grew out of technology probes can be better defined as *exploratory prototypes*, since many do not have the 'required' features of probes (such as being longitudinal) or of technology probes specifically (such as self monitoring). They argue that 'continuously usable prototypes' are the ideal as the goal is to evaluate use, misuse and nonuse and also to rapidly update in response to the observed activity. However, these continuous use prototypes are viable only in scenarios where *updatability* is easy and where usage of the system is expected to be intense - for instance, they discuss the ideal case being a web based client/server system accessed via standard browsers where the researchers can modify the content and push it to clients trivially (Heyer and Brereton, 2010). This also builds off existing rapid software development tools and methods. For less 'standard' embedded systems, this updatability can be harder. Embedded systems may be updated OTA (over-the-air) given appropriate system architecture and network connection, but more complex networks of systems are difficult to test and update in place. It is also non-trivial to update physical characteristics. That being said, these technical or logistic issues do not *preclude* the use of this kind of prototype for situated computing, although they may increase the cost and complexity. The aspect that is more problematic for these kind of systems is the rate of usage, the explicitness of usage and the nature of 'community' usage in a time-fragmented community. You can give a family a device and ask them to use it. You can give an individual a device and ask them to use it. But how do you give a *transient community* a device and ask them to use it? People are not in the garden continuously. The *same* people are not in the garden continuously. For devices that are not 'invoked', how can you tell if they are being used or shaping the interacting with the space? This becomes particularly an issue with designing systems that 'move out' (Furniss et al., 2015) from a single device or task and into more complex mutlidevice multiagent settings. It is also possible to argue that this focus on single continuously usable, updated prototype places emphasises the more 'traditional' elements of the design; it is well suited to improving mature technology or established practices, but lacks the *provocative* nature that Gaver, Dunne, and Pacenti (1999) Cultural probes were seeking, and that Boehner et al. (2007) argues is the element that is often lost in 'probes' in HCI.

The rationale for the specific design of the prototype is discussed in the Prototype Study chapter; the same kind of design decisions need to be made when creating 'full' RITW deployments, and some adaptions to the RITW framework that arise from this are developed in the Discussion chapter. The prototype consisted of two parts: sensors embedded in the garden which collected light level data over several months, and two different interface prototypes that revealed the information in different ways (a 'Situated' augmented reality representation and an'Overview' map representation).

Participants were recruited from one of the community gardens investigated during the earlier case studies (chapter 4), through a combination of opportunity sampling and snowball sampling. These participants took part in activities using both the Situated (augmented reality) and Overview (map) representations in individual session in the garden.

The audio recordings from each participant were transcribed and coded, and analysed using thematic analysis[4].

3.5 Research Ethics

All studies in this thesis were conducted under a 'program of study' ethics application, approved by UCL Interaction Centre's ethics chair (ethics number UCLIC/1415/004/PhD Rogers/Jones).

3.6 Conclusion

This chapter presented a broad overview of the structure of the overall method and research activities. The next four chapters of this thesis present each of these four research activities in turn (starting with the contextual interviews in chapter 4), detailing the rationale for each and showing how each activity contributes to the arguments in this thesis. These chapters are followed by a discussion chapter which ties the results of each research activity together and presents the contributions of this research along with discussion of the results and the implications thereof.

[4]This study focused on a specific system and specific research questions and so for this study the analysis was much more focused on the areas of interest than earlier analyses which were more interested in emergent themes - in Braun and Clarke (2006)'s terms, it was a *theoretical* rather than *inductive* analysis. Having said this, both the earlier analyses had some level of theoretical drive initially (over and above inherent subjectivity), and especially following the recontextualisation using situated action as a lens. In general, the analysis could be said to move along a spectrum from being more *inductive* to more *deductive* over the course of the research.

4 Contextual Interviews at Community Gardens

4.1 Introduction

Initial contextual research was conducted with gardening communities in order to learn more about growing practices in these communities. Current practices and information artefact use were investigated in a range of different community plant growing settings, using a modified grounded theory approach for the collection and analysis of data. On-site interviews were conducted with members from 5 different gardening communities (see subsection 4.3.1), using situated action as an analytic lens; this initial phase of research aimed to examine commonalities amongst different groups and additionally to explore which types of groups might be most interesting for further study. For the purposes of this study we investigated 'community gardeners' - defined here as a community who are working together to grow plants in a shared space. This potentially covers a wide range of motivations and approaches to growing, but with a focus on *co-located communities* rather than distributed communities or networks of individuals (such as traditional social media structures or concepts such as hyperculture (Geiger, 2014)), or individuals working in parallel in subdivided plots (such as in allotments).

4.2 Research Questions

This phase of the research aimed to address all three of the overall research questions laid out in chapter 1. Exploring existing context and the way in which action currently emerges helps to lay the groundwork for RQ2 (related to action in shared spaces) and RQ1 (relating to the specific community gardening domain). It also allows us to reflect on how this process works within the RITW framework, and how we might use this experience to adapt the framework (addressing RQ3).

In order to address these overall research questions, the following study-specific research questions were formulated:

1. How do actions (such as planting, maintenance, weeding and coordinating volunteers) currently emerge within these communities, and how can we design to support this?
    - What are current practices related to 'decision making' in the shared space?
    - What tools and materials are being used?
    - What are the challenges and opportunities for design?
    - Addresses RQ1 and RQ2
2. What can we learn about the RITW framework and how to apply is from this process?
    - Addresses RQ3

4.3 Method

Data was collected using semi-structured contextual interviews across 5 sites in and around London, with capture of additional contextual data (such as artefacts) using photographs.

4.3.1 Participants

Gardening communities (Table 4.1) were selected for the initial case studies by a combination of opportunity sampling and theoretical sampling (see the Methodology Chapter earlier), and were all contacted initially by email. Gardening communities were identified via existing contacts, suggestions by other groups, or found via project websites and project listings. The criteria for inclusion were that the community had to be involved in the communal growing of plants[1]. Given the variance in the nature of the communities, the character of each is briefly described:

Table 4.1: Groups and participants

Group	Participant Pseudonyms
The Glasshouses	Rachel, Heather
City Farm	Robert
UT3A technology group	Mike
Orchard	Alicja
Forest garden	Jen, Chris

nb Participants' names have been changed to protect their anonymity.

The Glasshouses

The first location was a community glasshouses in Inner London. At this location an interview was conducted with Rachel and Holly, who run a course there for adults with learning difficulties.

Rachel leads the course, and is a gardening tutor and professional gardener. Holly provides learning support for the course, is an experienced gardener, and also maintains an allotment.

This group is not concerned with *yield*, as they are more interested in education. Specifically, Rachel and Holly are focused on supporting their learners in achieving their learning goals. They believe that keeping the plants alive and healthy is important in helping to meet these goals, and to motivate the learners. However they do not need to optimise production in the same way that a business might.

Additionally, Rachel and Holly are also interested in more subtle forms of education - for instance, the iron railings between the glasshouses have

[1] In principle, commercial groups (such as co-ops) would have been included, however in practice all of the communities in this study were not profit-making concerns.

been used as the structure for vertical planters, to *'demonstrate to visitors they can grow stuff anywhere! (Holly)'*

Different groups use the glasshouses on different days, and no one person or group has responsibility for garden tasks such as watering. In practice, *"whoever's there at the end of the day"* waters the plants, *"as and when"* (Holly). This lack of clear responsibility means community members are not sure if plants are being watered when they are not there *"It just happens… I assume someone comes in over the weekend? I hope they do!"* (Rachel). Additionally, it is not always clear if plants should be watered, if they are not 'your' plants and the watering requirements and last watering are unknown. *" I get nervous about watering other people's things"* (Holly). Holly consulted Rachel about a specific instance of this very problem, and Rachel recommended watering in this instance based on her experience. Not all community members are able to make such a judgement.

Rachel and Holly described common maintenance tasks such as watering and weeding as 'boring jobs', as opposed to more interesting activities, such as propagation. However, there are benefits to doing these 'boring jobs' - for instance, some of the of the learners reportedly really enjoy watering, some weeding - Rachel and Holly believe that these have a therapeutic effect for these individuals. Although Rachel and Holly initially discussed irrigation systems (such as those Rachel sometimes works with in clients' gardens) as being useful for saving time and keeping plants in good condition, they were concerned that such systems would impair communications and community development. A nuanced position became evident as Rachel and Holly discussed watering and moisture levels. They were initially envisaging a system which indicated when things needed watering - a 'watering app'. However, the more they talked about this, the less they liked it; *"we communicate [face to face] less and less…"* - *"something that beeps… instead of people talking… I don't know"* However, a system which simply indicated relative levels but did not prescribe any action was much preferred: *"Could they [capillary mats used to retain water] just… glow when the water is low?"*

Many of the planters and other artefacts are made from scavenged materials. Everything from apple crates to old boots have been pressed into service as planters, and the furniture, tools and the glasshouses themselves are repurposed. The cost constraints and volunteer basis of the organisation drive this culture of appropriation, but it is also part of the ideology of the community. It doesn't appear to be an explicitly articulated 'sustainability' ideology, but more of a 'make do and mend' attitude (*"In a community garden, you've got what you're given - you inherit a lot of stuff, and you have to make do with what you've got"* - Holly), and the sourcing and repurposing of materials is an important community activity contributing to the character and aesthetic of the glasshouses.

"Things get done" when they discover a volunteer has a specific skill set, and spare time - for instance, one volunteer put in a new sink as he had the necessary skills. These job /skill matchups are entirely serendipitous, and decisions about acting on them are taken in an ad-hoc manner.

The majority of the plants in the Glasshouses have plastic stakes in the soil next to them, with attendant metadata (such as the plant name or species) - the adding of data to plants is clearly part of practice. Other typical data includes type of plant, date of planting and who 'owns' that plant. The growing space already contains a wealth of data, directly displayed on the relevant plant. Its easy to imagine adding dynamic data to this display with minimal interference; indeed, serendipitously the stake form factor is convenient for sensor packages that must sample the soil (due to soil anchor and visible informational area).

City Farm

The second location was a city farm in East London. Multiple site visits were undertaken, and onsite interview conducted with Robert, who looks after the community gardens and facilitates volunteers.

Robert is employed by the city farm to look after their community garden and coordinate the community. He has been working there part time for

2 years, and volunteered for 4 years before that.

The garden is used by a variety of people, with many people *"…just visiting to walk around and enjoy the garden"*. Due to the location the volunteers come from a range of cultures, age groups and backgrounds. There is a small group of 'hardcore' volunteers who attend regularly during the week. The majority of volunteers are infrequent and tend to *"arrive in waves"*.

Unlike the Glasshouses, boosting yield *is* an explicit goal for this community, although it may not be as heavily weighted as in commercial growing. Robert's primary goal for the garden is to *"produce [large amounts] of food"*. This supports his ideological goal of feeding people in a sustainable manner. *"this patch here can fully feed 20 families for a year"*

The farm as an entity has additional goals - community engagement and broad participation, and many volunteers are seeking *"increased closeness with the land"*. Although the city farm is interested in teaching people how to grow, they are also interested in wider education and awareness building about where food comes from rather than simply teaching growing techniques. This is particularly the case in the community garden where many people visit as opposed to volunteer.

The viability of the garden appears to help with motivation and engagement - not only did Robert directly state this was personally the case for him, but additionally areas that are not seen to be producing are disliked by the volunteers.

There are a number of physical artefacts and systems used around the gardens to convey information and *"bring some order"*. There are large chalkboards at each bed, which show which type of plant should be planted there. These signs are multilingual, and are also colour coded to match colour coded spoons in the propagators (Figure 4.6). The signs rotate around the garden on a three year cycle, rotating the crop types and preventing disease buildup and nitrogen exhaustion in certain beds.

Individual stakes are used to mark specific plant types/species , along with additional metadata such as planting dates. Big signs are longer term, strategic, smaller stakes are more immediate, more frequently moved and updated. Many volunteers are first generation immigrants to the UK, and some do not speak or read English and in some cases can't read any languages or can only read 'minority' languages (as opposed to the official language/s of their origin nations). This means that written instructions must be multilingual (as can be seen on the stakes and signs, which are in at least English, Bengali and Turkish Figure 4.1), and it is not guaranteed that everyone will be able to understand written instructions - the propagation area uses physical position to denote which stage of germination and growth the seedlings are at, along with lollipop sticks marked up with pen, and colour coded plastic spoons.

Figure 4.1: Multilingual signs at the City Farm. Note the colour coding, which matches the colour codes on the propagators.

The gardens use a minimal water approach, by using lots of moisture rich organic compostables. Although there is a rainwater butt as a backup store in case of extreme drought, Robert believes that normal rainfall is sufficient to water the gardens. Despite this, some people get a feeling of satisfaction from watering - *'people do it because they've "done a good job" and they feel good about it'*, even though *'they're just spraying water on the leaves, but theres a big smile on their face'*.

Not all volunteers contribute equally to garden tasks according to Robert, however that doesn't mean they are not deriving benefit. For instance, one group who visit together do a lot of work on the gardens, whereas another group are less able to do much manual work and mainly engage in socialising. However, Robert believes both groups get a lot of enjoyment and benefit from visiting.

There were broadly two types of decision making - immediate in the moment decisions taken by the volunteers currently present, typically on planting and maintenance decisions, and longer term quarterly meetings; however the people who turn up to the meetings are typically not the same people who are the regular volunteers.

University of The Third Age (U3A) Technology Group

The third setting was a village, where a University of The Third Age group are designing and producing a DIY irrigation system to support their local community's bid for the *In bloom* competition. The founder of the group (Mike) was interviewed at the site of intended deployment, and the group was observed while they were on a fact finding visit to a workers' collective that produces high tech agricultural sensors.

This group is a also a bit different from the others, as rather than being driven by an interest in growing, they are driven by an interest in technology, and have identified supporting their local community via automated irrigation as an interesting and worthwhile project. Also, the location is more peri-urban or sub-urban than urban.

The University of the Third Age (U3A) is an organisation dedicated to continuing learning into semi-retirement and retirement. A 'self help learning co-op', they believe that just because people are coming to the end of their career arc, they should not stop developing and learning. U3A local chapters are self-organising, and consist of a number of subgroups, which are also self-organising. Mike is the founder (and *de facto* leader) of this particular subgroup, who have been teaching themselves embedded hardware prototyping and programming, using the Arduino open hardware platform.

They have decided to put their skills to practical use ('there's only so many ways to blink an LED'), in order to provide motivation for continued learning and to push the envelope of their knowledge and abilities by tackling a real world problem.

The group is tackling the problem of irrigating the decorative planters around the village in order to maintain the flowers and increase their chances of going up a bracket in the 'In Bloom' competition. I interviewed Mike about his group and their plans, accompanied the whole group on a visit to a workers co-operative who make commercial and academic grade plant sensors, and attended the group's installation of demonstration planters.

For this group, learning about new things is the primary goal. The *In bloom* project gives them an opportunity to construct something with a purpose, which keeps the group motivated to meet their learning goals. The ease of using the Arduino platform (in comparison to custom building hardware) has had a huge enabling effect on this group. *"Devices like this allow you to design stuff without having to design the hardware' 'Its amazing'. Costs are not the same as in commercial operations, neither are the goals. This group in particular are very time-rich* - "at our point in our lives, we have *plenty of time* ". The commercial requirements of optimisation and shaving labour costs are irrelevant, and the group is not interested in mass producing identical items, nor do they need precision or long equipment lifetimes.

Materials re-use is also observed in this group - for instance, the planters use ex-industrial chemical carboys as internal lining, and the pumps they are using have been appropriated from their intended use in fountains. Interestingly, there is also a requirement to adapt to existing architecture/ infrastructure; the group has some impact on the design of the planters to be installed, however there are many areas where the infrastructure is pre-existing and the group needs to find design solutions that are parasitic/ symbiotic on the architecture. One example is the war memorial planter - the group is planning ways to take advantage of the architecture (such as putting water tanks in the hollow bench), as altering the fabric of the planter has practical and bureaucratic hurdles, not to mention moral and aesthetic concerns about interfering around with an emotionally charged piece of architecture.

Mike believed that as the project progresses, a gulf of knowledge is opening between the 'techy' people in the group and those who are less engaged in the technical aspects, and it seems likely that without Mike's championing of the technical aspects the project would not continue. Even in this highly motivated, time-rich group, the 'barrier to entry' to creating such a system is still high.

Organising meetings and keeping people engaged with group email can be difficult - *"once people miss one meeting, they are out of the loop."*. Many decisions appear to be made in settings outside of the official meetings, when group members are physically present together.

At the eventual demo planter installation, Mike and group were unable to install the automated watering system as the leader on the growing side (who is also part of the tech group) felt there was not time. In discussion afterward, a 'sensing only' approach was suggested - the implication being that the moisture data alone was the most useful part of the system. It is possible that this was suggested as a compromise, as the sensing part is less invasive/requires less alteration to practice, rather than a representation of underlying utility, but it seems telling nonetheless in the light of other groups negative feelings about automation.

Orchard Project

The fourth location was a community agroforestery project in Greater London. The leader of the group, Alicja was interviewed at the orchard whilst participating in land clearance. Unlike other participants, Alicja was not explicitly concerned with learning and education. However, she talked about volunteers developing skills and learning from more senior volunteers, and discussed the school groups and special areas they are constructing for them - for Alicja, learning is an intrinsic part of tending the orchard, rather than an explicit goal. In this sense, education was an adjunct to the goal of creating a self-sustaining orchard - this is the opposite of the U3A group, who were using the growing domain as a lens for education. Much like Robert from the City Farm, Alicja demonstrated a tension between wanting to include people and wanting to do things her way. Alicja's feeling is that as an expert in agroforestery, it is frustrating when volunteers without that expertise want to do things differently - *"People want to do things their way... You kind of have to let them do it... Then I go round afterwards and put it back the way it should be"*. Again like with the City Farm, there is a large expertise difference coupled with a sense of ownership.

Dedicated volunteers are rare in this project - there are only 3 core workers (including Alicja) at the project who are there every week. Regular volunteers move on, making it hard to retain expertise. Transient volunteers are typically low expertise, or if they have growing expertise they do not specifically have orchard or agroforestry knowledge.

The project has a home made water capture/storage system (Figure 4.2), and I observed discussions of how they could make it work as an irrigation system. Some of the saplings were being grown in pots made of newspaper (Figure 4.3), and there were large piles of construction materials (york bricks and timber) donated by local businesses. Similarly to other sites, this reuse was coupled with dedicated tools and materials - for instance, the water butt was purchased as such, but the infrastructure it is attached to are plumbing and roofing materials.

An automated tiller was in use, and the orchard community is planning to get a brushcutter and chainsaw - these are all tools used in larger commercial concerns (albeit here they were smaller versions - the tiller for instance was lawnmower-sized as opposed to being vehicle/robot mounted).

Alicja clearly feels that she is the core group member - it was clear from observing her interactions with the other volunteer on site that she was very much in charge. Alicja handles the publicity and fundraising for the group (which is a big task), and mediates meetings and decision making.

Alicja described her motivation for working at the orchard as an *"atavistic"* desire to *"get close to the soil"*, and that other regular volunteers felt similar. Many of the transient volunteers were engaged in a kind of informal bartering - Alicja indicated that after a few hours work, they would pick some fruit. This was not a formalised arrangement, but just something that happened naturally and 'seemed fair'[2].

Alicja was emphatically not interested in growing anything that you couldn't eat or use in some way. This seems to be similar to Robert (City Farm)'s desire for yield - the practical outputs of the project are important to Alicja and Robert. Alicja was specifically interested in growing items that were hard to get from the supermarket - rather than yield *per se* she appears to be interested in *impact*. This highlights an important facet of non-commercial (and potentially some small-commercial growers) - success is not necessarily measured in commercial terms, so managing the garden is *not* an exercise in optimising cash production. Indeed, Alicja is *"... not*

[2] Was I as a researcher engaged in the same bartering process? - after being shown around the project, I conducted most of the interview whilst breaking ground for new planting. Again, this was not an explicit agreement between myself and Alicja, but it *felt* socially appropriate. This raises questions about the place of the researcher in this kind of research - not only is the researcher having an active impact on the subjects by 'taking part', but with the exchange of goods/services (however implicit) they enter into a transactional relationship.

Figure 4.2: DIY water capture at the Orchard

Figure 4.3: Seedlings in newspaper

interested in getting them [restaurants] 50 tonnes of carrots". Restaurants want lots of staples - the volunteers at the orchard are not producing that type or volume of food and are not interested in doing so, even though it would be much more commercially viable. The location of the site (deep in an allotment, which itself is hidden away on an unlikely sidestreet) means that there is no passing traffic, and it is quite hard to find and get to from the road - this means that it is difficult for the project to distribute produce direct from the orchard.

Forest Garden

The fifth location was a community forest gardening project in North London. The founder of the group (Jen) and an experienced member (Chris) were interviewed on different occasions, and the researcher took part in a number of volunteering sessions. This group was selected for further research which is discussed later in chapter 7.

A forest garden attempts to model a forest edge ecosystem, focusing on sustainability, biodiversity and utility. The Forest Garden's goals are to create and maintain a forest garden, to promote temperate forest gardening through teaching and example and also to propagate plants that can be used by other organisations. This group had explicit learning and teaching goals, both at an individual level and in terms of raising awareness in the broader community; the layout of the garden reflects this, with an 'edible showcase' bed immediately on entry as a demonstrator for visitors, even though this area 'isn't really suitable for forest gardening' (Jen) because it is too exposed. Viability and yield is an important goal for members of this group - part of their philosophy is that the garden should produce food, medicine and ecosystem services(such as providing a place for wildlife to live). This sometimes conflicts with teaching and learning - for instance, the group engages in cloning and grafting every year, mainly as a teaching exercise. Grafting is the practice of attaching parts of plants to other plants to gain characteristics of both - for instance, grafting an apple variety onto a different type of apple tree which has a more robust rootstock but less pleasant fruit. Jen indicated that the repeated grafting was not good for the trees, since it carries a risk of infection.

Volunteers worked at the Forest Garden twice a week on Mondays and Fridays, with the number of volunteers being very variable (from one or two to ten or more). There are a core group of volunteers who attend regularly, often alternating their attendance in order to lead volunteering sessions. On some occasions when I visited, the leader for the day was the only person in attendance, on others there were large groups. Tasks in the garden come from two main sources - regular and scheduled tasks which are noted in a jobs book, and activities that the volunteers want to do. This is guided both by immediate circumstance, but also by the particular interests of the volunteers (such as Jen's interest in mycelium leading to fungal doping activities). Both Jen and Chris described decision making around what to do as being informal and ad-hoc, especially with regards to the exact direction of the activities; they described decision making as collaborative, however I observed that volunteers sometimes deferred to people they perceived as having more experience.

As in other gardens, there were a number of physical information-carrying artefacts in the garden: similar signs and stakes, and additionally map and job books in the greenhouse. The greenhouse also contained gardening books, clippings and other sources of domain information not necessarily specific to the space.

4.4 Results

The data was analysed using modified Grounded Theory, as discussed in the Methodology chapter.

7 Key concepts (Table 4.2) were formed from clusters of open codes.

The 7 key concepts were grouped into 3 Central categories, **Emergence of action**, **Learning and experiencing** and **Tools and materials**.

A core theme running through all the concepts was the importance of presence in the garden. We use ‘presence’ in this case to describe the experience of being fully in the natural environment, interacting with the garden. Participants described this as ‘getting hands in the dirt’.

Table 4.2: Grounded theory analysis: Key concepts and Central Categories, formed from clusters of open codes

Concept	**Central Category**
Decisions are often ad hoc and in the garden	Emergence of action and group structure
Volunteers skills and time is unevenly distributed	Emergence of action and group structure
Champions are important	Emergence of action and group structure
Learning and education is very important	Learning and experiencing
Getting close to the dirt is important	Learning and experiencing
Reuse of materials, tool archetypes and bricolage	Tools and Materials
Information carrying artefacts	Tools and Materials

4.4.1 Emergence of action and group structure

Participants across all locations report ‘decision making’ as being ad-hoc, collaborative and *in situ*. Not all community members have equal weight in this collaboration however; ‘Community champions’ are the most active in decision making, in part due to greater knowledge and in part due to greater ownership. There is much variability in volunteers skills, knowledge and in the time that they spend at each site; core members tend to have more experience of their particular site and are present more frequently, but even these most dedicated volunteers are not always in the garden and have limited total lifespans.

Participants report ‘decision making’ as taking place collaboratively, in-situ and in an ‘ad-hoc’ manner

Most of the participants at the five settings perceived their actions as being ad-hoc, collaborative and in-the-moment. Participants described ‘decision making’ as informal and ad-hoc (“We just wing it” (Forest Garden-Jen)), and being highly reactive to the immediate circumstance: "[it's a] bit haphazard … we've got this where shall we stick it?" (Forest Garden-Chris). Participants also described this 'decision making' process as being collaborative, but that this collaboration was restricted to those present at the time, rather than being a whole group collaboration - *"whoever's there gets to decide!"* (City Farm-Robert). When observing these 'decisions' being taken it is clear that although they are typically in the moment, they are informed by knowledge about the space and the domain. Reference is made to domain knowledge (such as wether particular plants prefer light or shade) and local conditions (such as how wet or dry particular parts of the garden are), and less experienced volunteers defer to more experienced volunteers (this is discussed further later in this section).

Volunteer time and skills are unevenly distributed

Not only does the composition of the group overall continually change as new volunteers arrive and old ones move on or reduce their involvement, but patterns of attendance and involvement for individual volunteers are complex and shifting. Some volunteers will only come for a single session, some will come every few months, some every few weeks; volunteering hours tend to be irregular and clumpy - there are surges of volunteers at certain times, and a dearth of people at others. One participant (City Farm,Robert) described large numbers of inexperienced volunteers as *"coming in waves!"* based on the time of day and time of year. Skills, local knowledge and motivations are transient - as volunteers get bored or move away, available skills will change, and projects get dropped due to lack of interest or knowledge. *"Once people are out of the loop… thats it"* (U3A group,Mike). It is difficult to teach and maintain knowledge levels in the community as a result; Alicja from the Orchard complained that *"people move on … its hard to build a team."* Even without the continuous slow change in overall group composition, at any particular point in time the makeup of the group at the garden will be different, leading to action emerging in different ways depending on those present.

Community champions are most active in 'decision making'

Despite the variability in the different groups interviewed, the existence of *community champions* was found to be constant; the specific nature of the structure different across groups, but certain group members (which we describe as 'community champions' (Taylor et al., 2013) [3]) were more active, more involved and had higher levels of ownership. Some community leaders (or 'champions') perceive themselves as experts and have a high degree of ownership of their projects - its clear that there is a tension for them between including and educating others, and 'doing it right' (City Farm,Robert). This seems related to the transient availability of volunteer time/skills, - the champions in these communities have a much higher level of expertise than occasional volunteers, making it difficult to scaffold learning by participation, and impairing community decision making. For instance, Rachel and Holly (the Glasshouses) have an expertise difference in that Rachel is more knowledgeable than H, but they are still both experts, and so can discuss things on an equal footing. Robert (City Farm) and Alicja (Orchard) however report being frustrated about community decision making because they perceive the expertise gap with causal volunteers to be so wide that meaningful discussion is difficult.

4.4.2 Motivations: Learning and experiencing

Education appears to be very important for all these communities - not just in terms of growing techniques, but also in raising awareness in the wider community about food and sustainability. Participants were motivated by teaching and learning from each other. The experience of being in the garden is also important to participants, with many participants enjoying

[3] Taylor et al. (2013) talk about *their* champion in the community - i.e. a community member who will champion the research team's involvement, research and technologies within the community; indeed, they argue that gaining access to a champion of this nature is extremely valuable when undertaking community research (Do, Cheverst, and Taylor, 2015). In our case we are referring more to these particular members being champions within their own community for that community's own core goals and methods.

‘experiencing nature’ and ‘getting their hands in the dirt’. Automated or prescriptive systems were perceived as negative, as participants felt such systems would interfere with the relationship with the garden and with other volunteers.

Learning and education is very important

Teaching and learning both within and outside the community was important to participants from all of the communities, even for participants who saw the primary remit of the community as not being educational in nature. Attitudes to learning differed - there was a spectrum from extreme learning focus, where the growing domain is being used mainly as a lens for education (U3A group), all the way to education being seen as an intrinsic part of the craft process (Orchard). However, across this spectrum, learning ‘while doing’ was considered an important part of knowledge acquisition for community members: *“There’s some opportunity for formal learning ... but you mostly learn by doing ... lot to be said for just being in the space and doing (Forest Garden-Chris)”*. Participants were also eager to extend knowledge outside of the community; areas of the sites that were most visible to the public and infrequent visitors were prioritised for demonstrations. For instance, the iron railings between the glasshouses (at the Glasshouses Figure 4.4) have been used as the structure for vertical planters, in order to *“demonstrate to visitors they can grow stuff anywhere! (Glasshouses -Holly)”*, and the ‘showcase’ beds at the forest garden (Forest Garden) are considered very important due to their visibility from the entrance to the site, even though the location is not optimal for planting, being *“too exposed, too sunny and too windy (Forest Garden-Jen)”*.

Getting close to the dirt is important, and automated systems get in the way

In common with previous studies (such as Goodman and Rosner (2011)), it was observed that ‘getting close to the dirt’ was important to participants. A number of participants talked about the need to be in the garden

Figure 4.4: Vertical planters on iron railings, and repurposed sinks as planters at the glasshouses

and to tend it and build understanding about it, in part to aid their understanding and skill acquisition, but mainly for the emotional aspects of the experience. For instance, (Orchard-Alicja) described her motivation for working at the orchard as an “atavistic” desire to “get close to the soil”.

Automated and overly prescriptive systems in the garden were felt to interfere with relationships with the garden, and communication and learning with others. For instance, Rachel and Holly (Glasshouses) discussed watering and moisture levels - ‘Boring’ tasks such as watering can take up a lot of time and it is not always clear if they have been done leading to errors such as overwatering or underwatering. Rachel and Holly were initially envisaging a ‘watering app’ system which indicated when plants needed watering. The more they discussed it however, the less they liked it; “we communicate [face to face] less and less…” - “something that [tells you what to do]… instead of people talking… I don’t know”. However, a system which simply indicated relative levels but did not prescribe any action was much preferred: “Could they [the capillary mats] just… glow or something when the water is low?” Interviewees also reported that some community members enjoy tasks such as watering, and interviewees at the Glasshouses and City Farm expressed a belief that such tasks can be therapeutic; even though at the City Farm moisture rich compostables are used to eliminate the need for watering unless there is a severe drought (an example of a low tech solution for reducing the need to water), ‘people do it because they’ve ‘done a good job’ and they feel good about it’, even though ‘they’re just spraying water on the leaves, but there’s a big smile on their face’ (City Farm-Robert)[4].

4.4.3 Tools and Materials

Tools and infrastructure are an important part of the gardens, and there appear to be a number of common forms which are constructed with im-

[4]It should be noted that this is an observation about *other* community members, made by community champions, rather than a comment on their *own* behaviour.

provised or appropriated materials - for instance, Forest Garden use old estate agent signs to make signs and markers. Much use is made of management tools marked up with information; there are *information carrying artefacts* that record information on the plants, others that perform coordinative functions, and others that represent domain knowledge stores. The plant information artefacts appear to have two forms; markers placed directly by the plants themselves, and overview representations of the same data in map form.

Physical data artefacts in use throughout each site

A number of information carrying artefacts were observed that were used for managing garden systems. These artefacts fell into 3 groups; local plant information, domain knowledge and coordinative artefacts, as shown in Figure 4.5. There appear to be two subtypes of local data artefacts - *situated* ones such as plant markers and *overview* ones such as maps. They contain very similar data, but in different representations and in different locations in the garden.

Local plant information artefacts

There are two subtypes of this type of artefact; those situated directly next to the plant that they relate to, and those that are located away from the growing area and that present the information in an overview form. Situated plant information artefacts, such as markers and signs, are marked up with metadata and instructions, typically recording information such as species types, planting dates and origin (Figure 4.6). The overview plant information artefacts are typically maps, recording similar information but in a cartographic representation (Figure 4.7).

Domain Knowledge artefacts

This type of artefact was typically located in sheds, shelters or offices adjacent to the growing space or in a distinct subspace within the garden, and represents sources of domain knowledge rather than being specific to the particular growing space, such as books and newspaper clippings on

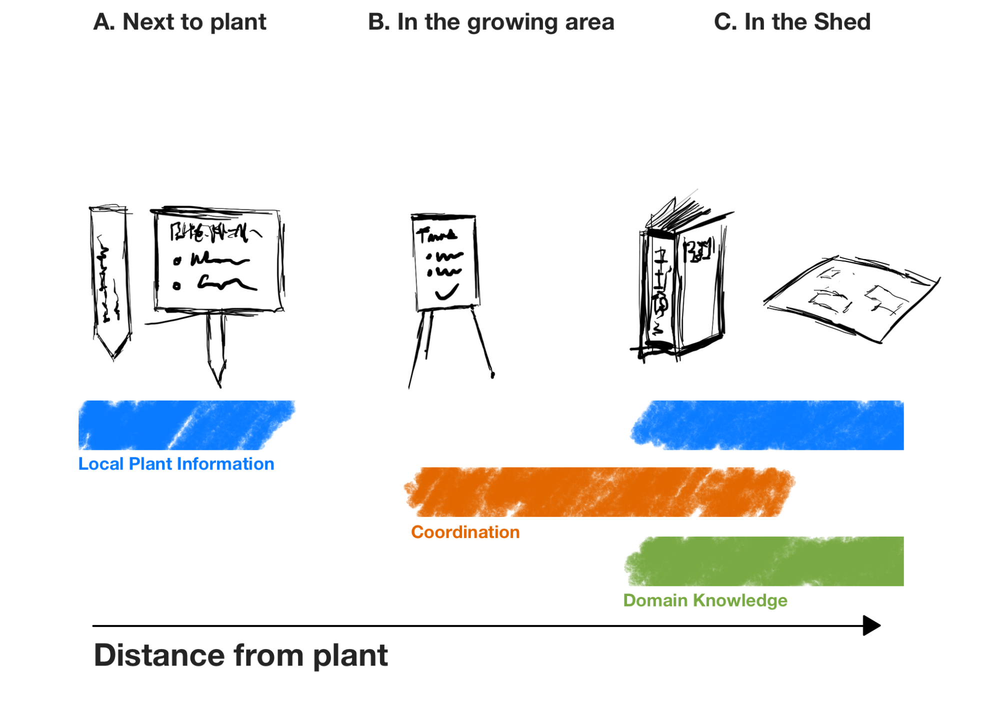

Figure 4.5: Types of information carrying artefacts and locations. A: Next to plants we see plant metadata on markers and signs, B: in the growing space, there are coordinative artefacts such as whiteboards, C: near the growing space we find knowledge artefacts such as books, coordinative artefacts such as task planners and plant metadata in notebooks and on maps.

Figure 4.6: Colour coded spoons and lollipop stick metadata at the City Farm

Figure 4.7: A book of sketched maps from the Forest Garden, showing different beds and plants.

plant care.

Coordinative artefacts

We also observed some examples of coordination tools such as whiteboards with tasks, and paper task books and planners. These artefacts were found with the domain knowledge artefacts, or outside in the garden but not associated with any particular beds or specific plants. For instance, the Forest Garden had a 'jobs book' in the greenhouse, so that volunteers could record what tasks they performed in a session. The book was also used to give notes to others on what jobs needed to be done at certain times, and specific instructions for specific volunteers. The City Farm had a large whiteboard with some general 'todos' written by Rachel so volunteers could direct their tasks and indicate if they were done. Broadly, the coordinative artefacts appeared to be attempting to manage communication between volunteers across different sessions, rather than within specific visits; they give indications to people who are sharing the same space, but not at the same time.

Materials Reuse and use of existing architecture

Reuse of found materials is common - from the Glasshouses's boot planter (Figure 4.8) to the Forest Garden's use of estate agent signs as raw material for markers and the U3A group's use of old industrial containers as planter liners. Recycling and reuse is important to these communities, both for sustainability and cost reasons. *"In a community garden, you've got what you're given - you inherit a lot of stuff, and you have to make do with what you've got"* (Glasshouses,Holly). It appears that gardeners have a toolbox of tool and infrastructure archetypes which they can either instantiate by purchasing or appropriating premade objects or tools (such as water butts and trowels), or by creating them out of found materials (such as the newspaper planters and lollipop stick markers). This process of bricolage is highly adaptable to local conditions, requirements and available tools; for example, empty plastic milk bottles are commonly produced as part of daily life in London, so everything from cloches to markers are made from this material.

4.4.4 Core theme : Presence and Physicality

A core theme running through all the concepts was the importance of *presence and physicality* in the garden. This underpins decision making, learning and teaching. By *presence and physicality*, we mean actually being in the growing space, interacting with it, and the experience of being there in the natural environment. Participants often referred to this as getting 'hands in the dirt'.

Being 'present' in the growing space is not just beneficial from a holistic understanding and decision making point of view, there is also a strong experiential component - getting "close to the dirt". Examining commercial devices such as the koubachi and edyn (see chapter 2), this physicality and presence is lacking, rendering them experientially unsatisfying.

4.5 Discussion

The first research question specific to this study was *How do actions currently emerge within these communities, and how can we design to support this?*

The findings show how ad-hoc, collaborative 'decision making' often occurs when situated in the garden. This suggests action is emerging in a colocated, collaborative manner. It could be argued that it is the forcing of these decisions out of the growing context and into more structured but less situated off site contexts that leads to resistance to sensing technologies. However, despite participants' reports, it appears that the emergence of action may be more complex: various information carrying artefacts were observed (such as maps and notebooks) that suggest that actions emerge on a scope wider than that of immediate 'in the moment' action, and additionally the social dynamics of volunteers means that 'collaborative'

Figure 4.8: Materials re-use at the glasshouses

actions are heavily influenced by community champions.

We saw across the communities that there was a loose and shifting structure of volunteers, whose time in the garden is unevenly distributed, with community champions forming a more stable core group. There is a transience to volunteer time and variance in skill levels, meaning that actions may emerge differently depending on who is in the garden at any specific time. As such, it's possible that the continuity provided by the champions is vital to the maintenance of effective action in the garden; it could be argued that the champions represent not just higher skill levels but also a thread of shared intent and community memory. However, although community champions represent more stable attractors in the loose structure of volunteers, the truly stable element appears to be the *place* rather than the *people*; even the most dedicated volunteers do not attend all of (or even most of) the volunteering sessions, and community champions move on due to other commitments or loss of interest.

It is also possible that the wide variety of information carrying artefacts observed in these garden spaces help to provide what Suchman (2007) calls 'autobiography of place' by externalising information into the space. The coordinative artefacts appear to track and direct tasks, whereas the plant information artefacts record information about the plants. Interestingly, the plant information artefacts do not carry information about local environmental conditions; the domain knowledge artefacts (mainly books) do contain information about the effects of various environmental conditions on plants, but local environmental conditions are not recorded. It is possible that augmenting these existing 'plant metadata' markers with local environmental knowledge would support the emergence of action that leads to greater ecosystem viability (how likely plants are to survive and be productive); for example, providing environmental information could enable community members to adapt planting choices more closely to the conditions.

It is also of interest that local plant information artefacts are present at both ends of the ‘distance from plants’ spectrum presented earlier in Figure 4.5; The information held in each appears to be very similar - as such it seems likely that there is some aspect of the different representations and/or locations of the artefacts that fulfil different roles in the emergence of action. Whilst it is possible that these redundant representations exist simply due to a quirk of practice or residue of previous behaviours, this seems unlikely given the prevalence across multiple sites. The nature of these artefacts and their different representations and distance from plants suggests potentially interesting avenues to pursue for understanding how action emerges in shared spaces (thus addressing our RQ2). This spatial relationship is investigated in later studies, ultimately building to the *Empirical* contribution of the thesis.

Teaching and learning were also found to be important motivators for all participants, not just for increasing that individual’s own knowledge (for use in the community garden or in their own garden), but also in order to encourage wider engagement; this is reflected in the prevalence of exhibition and demonstration beds in the different projects. The physical space of the garden is central to much of this learning and teaching. Skills are learned and shared through action and knowledge is gained by participating in discussions and ad-hoc decision making and experimentation: participants emphasised the importance of ’ learning by doing’ (Forest Garden-Chris) over formal teaching. Hence, this suggests that situating environmental information into the growing space could support this learning focus; not only could the data help community members to acquire knowledge about the environment, but additionally shared artefacts support learning via peripheral participation - for instance when experts are discussing a course of action and novices are peripherally involved.

Overall, these findings about the emergence of action and current practice in existing contexts are helpful in addressing our overall RQ1, and building towards the *Domain Specific design implications* contribution of this thesis.

The second study-specific research question, in service to the overall RQ3, was *What can we learn from this process that we can use to extend the RITW framework?*

We needed to lay some groundwork and develop an initial understanding of the context *before* committing to a RITW deployment. Even for settings where there is some existing contextual knowledge or a pre-determined site or event (such as when driven by communities rather than researchers), there will still be stakeholder meetings and other kinds of work that need to be done. Although the RITW framework doesn't have an inherent ordering (unlike cyclical approaches such as User Centered Design), we still need an entry point, and using grounded theory and interviews offered a good exploratory investigation. As a result of conducting this research activity, the contextual findings have allowed us to start thinking about what kinds of technologies would be useful, and how these could be applied to the community garden. These findings have allowed us to begin to formulate questions about design that we can use to frame the next phase of the research. For instance, the plant information artefacts we observed suggested that the 'situated' subtype represented similar information to the 'overview' subtype, albeit using a different form of representation and in a different location within the growing space. This led us to consider the following questions: Why does this redundant information exist? Are both types involved in the day-to-day emergence of action in the garden, and if so what roles do they play?

Reflecting on these contextual interviews, *RITW is more iterative than it appears*, there is *an ordering to activities* that the framework doesn't capture, and it feels like there is an *emerging theory* of what is going on that is not explicitly represented in the RITW framework.

4.6 Conclusion

This chapter has presented the findings of a study using contextual interviews to discover more about plant growing communities in and around

London. This initial research showed a strong focus on learning within the environment, with community members valuing “learning by doing” and “getting close to the soil”, and decisions being made in situ and in an ad-hoc manner. Automation in general was disliked as it was felt it would disrupt their relationship with the physical space and with other community members. Existing tool use and management items (such as plant information markers) were observed, along with common tool forms and materials reuse.

Presence and physicality in the garden was a core theme throughout, underpinning decision making, learning and teaching and the nature of data tools; the physicality of the space and the importance of being embedded within it was involved throughout all of the themes.

These findings about context and practice in the garden laid the groundwork for addressing our RQ1, and additionally began the development of our understanding of shared spaces (RQ2): Taken together, the findings suggested that *augmenting existing tool/infrastructure practices* (for example, by adding environmental data to plant information artefacts), could support collocated coproduction of action in a manner which will be accepted by community groups.

In order to investigate the potential of new technologies to augment existing practice, a Design Workshop was conducted (see the following chapter).

5 Design Workshop Study

Many thanks are due to Dr Marta Cecchinato and Dr Temitayo Olugbade, who assisted with the setup and running of the study presented in this chapter, and to Christie Lau for photographing the workshop

Following the interviews, it was decided to run a design workshop to explore how novel technology could be used to augment garden practice. Specifically, a participatory design workshop was held to introduce members of community growing groups to novel sensing and interaction technology, to elicit their responses to sensor technology as a tool for use in the garden. The workshop followed a similar *learn-discover-invent* strategy to that used by DiSalvo, Lukens, et al. (2014) in the *Growbot Garden* series of workshops, but with a focus on sensing rather than robotics. Thematic analysis was performed to extract key themes from the workshop.

5.1 Motivation

The initial interviews showed the importance community gardeners place on ad-hoc, situated decision making in the garden and the importance to current practice of *being in the garden*. Participants were conceptualising 'technology' as laptops, tablets and phones - screen based devices that they felt 'got in the way' of gardening, taking people out of the garden physically or mentally. From this we can consider that some kind of situated decision support system could be useful, and that it should avoid being 'screen based', but what form should this system take? What *specific* problem should it solve? Which tech should we choose? For instance, local sensors or remote imaging? Some kind of embedded sensor network, or tools that can be carried around and used to sample the environment? And how would this be designed?

In order to to narrow the design space for a Research In The Wild deployment, we used a design workshop intended to get community gardeners thinking about novel technologies and how they could use them for things that matter to them, and think about how they *might* use as yet non-existing systems in the future.

5.2 Research Questions

This phase of the research aimed to address the overall research questions RQ1 and RQ3, with the workshop outputs intended to help shape technology and design choices for the research project, and also allowing reflection on the workshop process itself and how this can be used to inform extension of the RITW framework.

As in the previous chapter, the overall research questions in chapter 1 are broken down into study-specific questions. The first three questions target both RQ1 and RQ3, and the last addresses RQ3 only:

1. What issues are gardeners concerned about that could be supported with new technology in the garden? *What problem should we solve?*
2. What technology approaches would best support their practice? *What should we build?*
3. What factors can support adoption rather than aversion? *How should we build it?*
4. What have we learned from this research activity that we can use to *inform our extension to the RITW framework?*

5.3 Method

Eliciting creative design in a field where the participants have no knowledge represents a balancing act - participants have to learn about the potential of the novel technology, without overly constraining their creativity. We want to introduce participants to the building blocks, without biasing them with the specific form of the examples or existing projects used for illustration. A learn-discover-invent strategy (DiSalvo, Lukens, et al., 2014) first introduces participants to the opportunities and possibilities a novel technology offers, then allow discovery of concrete examples, followed by creative activities. This is intended to 'open up' participants' minds to new possibilities for thinking about technology, rather than focusing on prevalent current consumer technology or biases against technology in this setting.

The workshop was designed to be run in four phases: 1) Introductions, 2) Learn phase, 3) Discover phase and 4) Invent phase, and ran for half a day (with a break for lunch between the first 3 phases and the Invent phase). Participants arrived at different times through the first part of the session so a more staggered approach than intended was taken to the earlier phases (the introduction, learn and discover phases), with different groups of participants progressing through the first three phases at different times. This was not ideal but did not impact on the co-design sessions as there were sufficient participants for each phase, and all the participants arrived by lunchtime, allowing the design phase to be conducted with all the participants at the same time.

5.3.1 Location and Participants

Location

The workshop was held outdoors on a weekend at UCL's premises. A variety of food producing plants were set up in the area in different life-cycle stages. This setting was to provide a context closer to the garden than a typical indoor workshop, and also to allow the participants to use the plants as design cues during the Discovery and Invent phases of the workshop.

Participants

There were 7 participants, all female[1]. 5 of the participants were members of at least one community food growing project, interested in the potential use of novel technology in their projects and 2 were interested in novel technology for their own gardens. 5 of the participants lived in London, 2 were travellers. None of the participants were drawn from the communities investigated in the case studies, as we wanted to draw from a wider pool of gardeners, and additionally were considering selecting from the initial contextual studies for the final deployment and didn't want to prematurely expose these communities to the concepts and design process, or tie the research too specifically to a particular garden.

5.3.2 Procedure

Introductions

On each participant's arrival, there was a round of introductions to help everyone to understand each others backgrounds and to ease people into the session. It was intended that participants would quickly sketch or build a representation of their growing space (e.g., garden, farm, etc), to encourage sketching/making by starting with a task based on something the participants know well and to ground the workshop in the subject domain, however the staggered arrival of the participants made this impractical for all of the participants.

Learn Phase

The goal of this phase was to familiarise participants with sensing technologies in use. The moderator delivered a short talk about the goals of the research, and of the workshop. They briefly demonstrated some

[1] **NB** We didn't recruit or select on the basis of gender, it just transpired that all the participants who attended the workshop were female. The implications of this in terms of representativeness and self selection bias are discussed at the end of this chapter.

of the technologies that are being used in agritech, such as environmental sensors and multispectral imaging, and providing examples of existing projects.

Discover Phase

In this phase, participants explored demonstrations of sensing technology and discussed possible usage in their situations. During this phase the moderators made observations and probed into challenges, current strategies and opportunities.

Sensors The primary materials in the Discover phase were a selection of sensors, representing some of the possibilities of sensing local environmental data as seen in commercial and industrial settings. These included a soil moisture sensor that participants could insert into different plants and see an immediate simple output (the brightness of an LED). There were also a number of identical moisture sensors, not wired up, for participants to examine and play with. There were also examples of air temperature/humidity sensors. The soil moisture sensors were selected as the primary sensor type because they can be moved between plants to see an immediate change, and watering plants shows a change quickly. The sensors were not placed in enclosures to discourage participants from seeing them as finished products, and also to make them less like mysterious 'black boxes' by revealing their working parts. When piloting the workshop stimulus materials and tasks, it was found that remote sensing (the other major approach apart from sensor networks) was difficult for pilot participants to interpret, both in terms of printed false colour maps, and real-time multispectral imagery visible through a Head Mounted Display; the sensors were more effective at eliciting interesting discussion, being playful and interactive but also understandable.

Input/Output boxes In addition to the sensors, participants were also given input/output boxes - sets of manual inputs and data outputs. These input/output boxes served a number of purposes. They allowed the ‘wizard-of-oz’ use of the sensors by the moderator and by participants, demonstrating non-screen data artefacts, and helped participants understand wireless sensor networks outside of the context of ‘something that talks to your phone’. Splitting up the sensors and the outputs allowed more flexibility than demonstrating an integrated wireless sensor network, as the different elements could be used and played with in different configurations. Additionally, splitting up the sensing and remote interaction concepts allowed workshop participants to learn each concept separately, which is both easier and less prescriptive in what can be done with the different parts.

There were two types of input/output pair, a LED (Light Emitting Diode) matrix and pushbutton pair and a LED bargraph and rotary encoder (or knob) pair. Pressing the pushbutton cycled a series of emoticons (Frown, Neutral, Smiley) on the matrix, and rotating the knob increased or decreased the number of lights on the bar. Clicking down on the knob cycled the colours of lights on the bar. These two types were chosen in order to present categorical and continuous types of input/output. The input/outputs needed enclosures in order for participants to be able to hold and interact with them properly, however the enclosures were deliberately lo-fi to discourage participants from thinking of them as finished items (see Figure 5.1).

Invent Phase

The participants broke into 2 groups, and each group attempted to design a solution for one of the challenges/opportunities uncovered and discussed during the Discover phase. Participants were provided with stimulus materials such as play dough, lego, pipe cleaners etc, in addition to lots of stationary.

Each group presented their design at the end of the session - this helps to elaborate on their thought processes, motivate production of a design, and provides other groups the opportunity to comment.

Figure 5.1: A push button input in a tea box. This was paired with a led matrix in a cardboard cube. Pressing the pushbutton cycled a series of emoticons on the matrix, demonstrating wireless categorical input/output.

5.4 Findings and Analysis

The majority of the findings come from the Discover and Invent phases, as the Introduction and Learn phases are experimenter driven and intended to set the scene for the study rather than to elicit responses from the participants.

In the Discover phase, the findings are based on participant responses to exploring the sensor demos, and their discussions around this. The researchers additionally probed challenges, current strategies and opportunities:

1. What are the **Challenges** that gardeners face
2. What are their **Current Strategies**
3. What **Opportunities** are there for design?

There were a combination of individual and group responses in the Discover phase, with participants who arrived earlier becoming involved in the conversation with later participants.

In the Invent phase, the findings focus on the design artefacts produced by the groups, and their presentations and discussions of their designs.

Thematic analysis was used to identify key themes from both phases. Session recordings, researchers' notes from the session, notes from the post session discussion with assisting researchers, and the design artefacts were used to generate initial codes. The codes were collated into themes, with the 'keyness' (Braun and Clarke, 2006) of the themes being based on a mix of prevalence within the dataset and level of fundamentality (Cairns and Cox, 2008). Whilst both Braun and Clarke (2006) and Cairns and Cox (2008) describe using a mix of these to construct 'keyness', they differ slightly but importantly; Braun and Clarke (2006) argue for assessing based on 'importance to the research' whereas Cairns and Cox (2008) simply describe fundamentality as something being '...deemed of fundamental importance'. The latter was used, as it is a more open definition, capturing not just theoretically driven importance, but also importance grounded in the data.

The themes derived from the analysis are presented here broken down by phase. First, themes from the Discovery phase are presented, grouped into the three areas we were interested in probing for this phase: Challenges, Current Strategies and Opportunities. Then, the two groups design artefacts from the Invent phase are discussed (the 'Sluginator' and the 'Birdbot'), followed by themes arising from the Invent phase.

5.4.1 Themes from Discovery Phase

Challenges

The biggest challenges were issues of *knowledge*, both in terms of general domain knowledge and specific local environment awareness.

Identification Is a recurring challenge - identifying plants, pests and disease can be difficult, especially pests not visible to the naked eye and diseases without obvious symptoms.

Diagnosing issues was also discussed by the participants. Not only does pest and disease identification play a part, but also working out why plants lack vitality due to environmental factors. *"You know there's something wrong... but what?"*

Weeds, watering and pest control were of importance to the participants; as seen in the interviews conducted in Chapter 4, these activities are repetitive and time consuming, however participants indicated that they did not want to automate them away. Watering decisions can also be challenging; one participant talked about how difficult it is to know *how much* and *how often*. On the one hand, participants said they didn't always know what the plant requires, and on the other is the problem of knowing the state of the plant. The group agreed that the 'finger in the soil' approach is not always reliable, as there are issues of water levels at different depths and a real danger of overwatering in a community context. Two participants mentioned living quite far from their communal plots, and not knowing if they needed to go to perform maintenance tasks or not.

What to plant, where to plant and when to plant were raised as the most challenging decisions. Participants felt that selecting what to plant and where to plant it was a hard problem as they didn't always know what plants would match their environment. This appears to be a *knowledge* problem (similar to the identification issues), but this is also largely an issue of environmental awareness; even if a plants preferred conditions are known in the abstract, working out if that matches the conditions in the growing space is troublesome. One participant commented *"How much light is the right amount? I just wing it … In theory I should go and test all year but can't get there"*. The lack of specificity in information sources, coupled with the vagueness of available environmental descriptors leads to a large space of possible solutions, and given the long cycle times of plants and difficulty in isolating success/failure factors. When to plant is also problematic - participants felt that initial propagation was quite well defined, but *"when to plant them out… thats the problem"*. As with what/where to plant, the issue of when to plant out is a combination of vague information and lack of granular environment awareness; many sources give general dates for planting out, but the changes over time of the garden environment are more important, and participants did not always know this - judging when it is safe to plant out requires a long record of daily minimum temperatures in the garden.

Current strategies

Participants mentioned a number of existing strategies to overcome the knowledge challenges observed. The typical approach was characterised as 'trial and error'. Performing 'experiments', and 'seeing what happens for next year'.

Books and online resources are a major source of domain knowledge. However, participants complained that books often lack information and are *“[difficult to] tailor to your own circumstances”*. Participants discussed searching for specific questions and pieces of information, but *“Google doesn’t always work”* - online resources were seen as being even less adaptable to local context than the information found in books, especially as many sources appear to be reporting what works for them rather than more generalisable parameters.

Another very important source of knowledge is to call on Parents. All of the participants indicated that their parents (or grandparents) were their best source of knowledge, being more adaptable than alternate knowledge sources; three of the participants said that even though their parents live in different countries with different climates, they are able to provide tailored advice, and they make lots of use of them when they visit.

Opportunities

The participants discussed a tool that would tell them what to plant and where to plant - this was proposed, then instantly retracted by one of the group … *“Actually, it should be better* don’t *plant this here … It’s good to know it’s definitely not going to work, but I don’t want to be told what to do”* The rest of the group agreed, indicating that they wanted ‘advice’, but not to be ‘told exactly what to do’. Community food growers want support in making decisions, but they don’t want the decisions made for them.

Some other tools that participants posited included a pest/disease identifier, a growth size tool to help decide how far apart to plant things, and remote garden watching to see information about their own and other peoples gardens. This was felt to be good for practical purposes such as co-ordinating shared tasks, but also *“because it’s fun!”* to look around others community gardens.

Found material aesthetic

Many participants commented positively on the aesthetics of the tea-box input/output boxes, indicating that they liked the 'low-tech' and 'DIY' feel of the boxes. This positive response suggests that gardeners may prefer repurposed/reused materials for technology in the garden, as opposed to polished industrial design.

In the garden feedback

Participants also talked about getting information directly in the garden (as a result of playing with the input/output boxes). They indicated that feedback directly in the garden is ideal, however they would also *"want it on my laptop later ... more in depth"* Specifically one participant gave the example of a smiley face in the garden vs a specific PH level on the laptop.

5.4.2 Design artefacts from the Invent phase

The outcome of the design phase resulted in the creation of two sets of design artefacts. One group (the Sluginator group) designed for pest identification and control. The other group (the Birdbot group) developed a system for understanding the growing environment. These represent different types of knowledge gap observed in the Discover phase: the Sluginator deals with domain knowledge (identification) and the Birdbot deals with local knowledge (environment awareness).

The Sluginator Group

This group created an anti-slug robot (see Figure 5.2,Figure 5.3, and Figure 5.4), which would patrol the garden identifying pests and areas attacked by pests and then dispensing appropriate pesticides. This design of automatically dealing with pests appears to go against anti-automation feelings mentioned earlier in the workshop. This suggests that seeing and using novel technologies afforded new possibilities for them that they

Figure 5.2: “The Sluginator”: the anti-pest robot designed by this group.

hadn't previously considered. Interestingly, the group that designed this said that it would be more for their own *personal* plots rather than for the community projects they are involved in. The group's design exhibited mixed autonomy; the group described it as identifying pests and informing the user 'when they are home', but acting fully autonomously to kill them when the user 'is away' for e.g. short holidays. Even when positing a tool with the potential to take over this task which was described as difficult and boring, the participants did not want to be excluded from the task. That the group felt the Sluginator was capable of handling the task in their absence indicates it is not a concern that automated systems can't be trusted, but rather a desire to be involved. The Sluginator design's primary purpose is *informational* - assisting in the identification of pests and thus allowing users to take informed action of their own. The automatic killing aspect seems to be secondary.

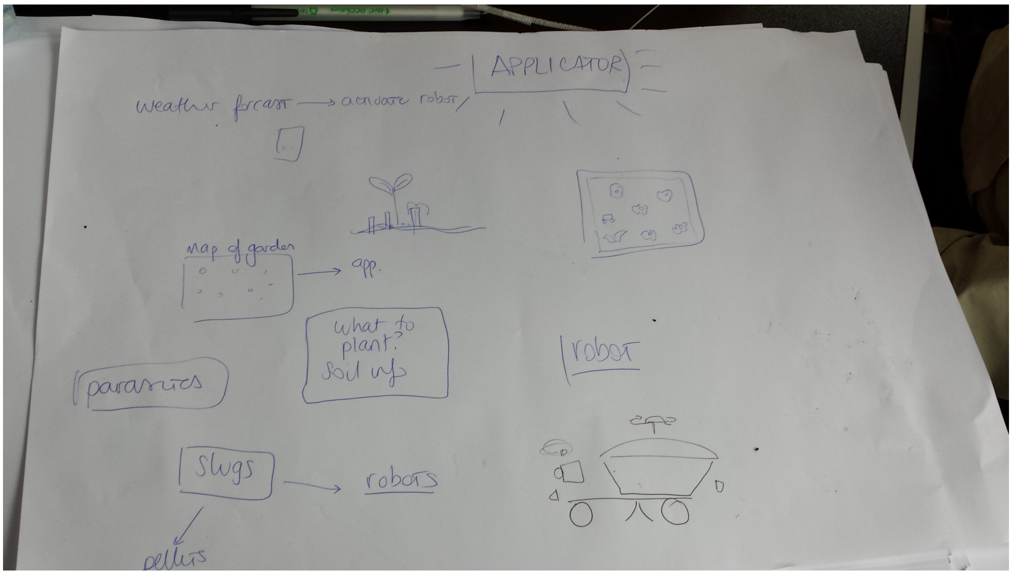

Figure 5.3: The sluginator system sketch, showing not just the robot but a tablet app component and various data sources.

The group imagined the sluginator as roving the garden and providing information on identified pests and possibly environmental data, either through some kind of visible behaviour or delivered to the iPad. They felt the robot should have two modes - one where it identified pests automat-

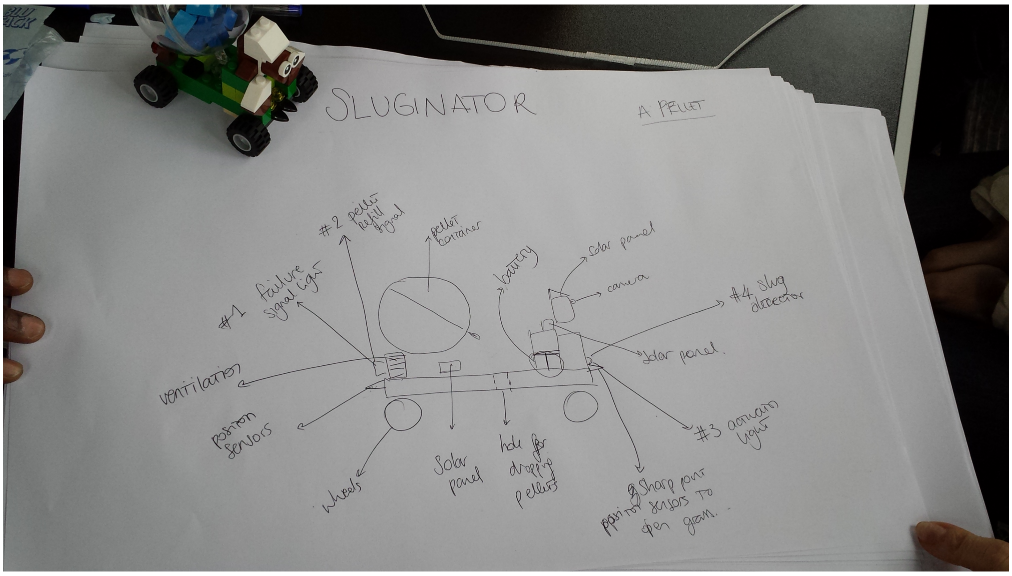

Figure 5.4: The sluginator robot design, and physical artefact made out of lego, play-do and other materials

ically but had to be additionally commanded to dispense eg pesticides, as the gardeners agreed that they wanted to make this decision themselves. They also designed an 'automatic mode' for when they were away on holiday or otherwise unable to reach the garden. Its notable that this is similar to the Burrell, Brooke, and Beckwith (2004) vineyard study - the desire for actionable information but not the removal of control.

The Birdbot Group

The Birdbot group designed a system based on 'natural things', intended for *"people who don't have a lot of scientific knowledge"* to understand the community growing space better. The prototype (see (Figure 5.5)) was designed to have multiple components; 1) the 'bird', which has sensors in the legs and eyes, and reports information by the movement of its wings, 2) the 'weeds' which are sensors in the ground that change their look according to how healthy the ground is, and 3) the 'tree' which shows users information from the 'bird' and the 'weeds'. The group described that weeds and animals are good indicators of the state of an environment, for those

Figure 5.5: The "Birdbot" system designed by the second team. This system uses multiple parts that mimic various biological entities to sense and convey information within the garden

that have sufficient knowledge about how to interpret them.This group wanted to mimic and extend these indicators to be more interpretable by novices, and to provide additional information so they could make better informed inferences about the garden. In part, this biomimicry appeared to be building on this group's existing knowledge - they were redescribing systems they already used and applying the sensor concepts directly to it.

Like the previous group, they embraced the affordances of the sensors and the artefacts to create a prototype to address a concern that was important to them - in the case of this second group, *local environmental awareness*.

5.4.3 Themes from Invent Phase

Physical avatars, biomimicry and zoomorphism

It is notable that *both* groups created a physical avatar as a core part of their design. In both cases, it represented a single overview point and channel for communication. It is also interesting that even the names the groups chose are associated with the avatars. This is fairly straightforward in the case of the Sluginator as an autonomous or semiautonomus agent. However, for the BirdBot where the avatar is only a part of a wider system it seems to suggest an assumption of a central point of overview and control within the garden. Linked to this, both groups also made heavy use of biomimicry and zoomorphism (meaning, having the form of an animal); the avatar in both systems was zoomorphic (strongly so in the BirdBot group), and all of the components of the BirdBot system mimicked biological systems.

On the one hand, this biomimicry may be a simple context effect - of 'things which are in the garden' plants and animals are very salient, and 'things which sense stuff and move visibly' tend to be animals, thus leading the participants to model these system elements as such. On the other hand, this may represent a deeper urge to map the technology aesthetic onto an appropriate aesthetic for the garden. One participant from the Birdbot group felt that replication of existing biosystems would make it *"easier to interpret for non-scientific people"*, and another felt that it *"helps teach people ..."* about the real equivalents (ie, that novice gardeners could use the 'sensor weeds' to learn how to interpret natural weeds).

Multiple levels of interaction and feedback

Both groups designed multiple levels of interaction and feedback- the Bird-Bot had layers of immediate local interaction and overview systems (with overlapping roles between the bird avatar and the tree), and the Sluginator had multiple levels of autonomy depending on the situation. The sluginator group also initially sketched some additional external interfaces (such as an iPad), but were unsure of their usage. The multiple levels seemed to be tied into the desire for a central avatar or overview component to act as a mediator or 'hub' for interaction.

5.5 Discussion

Participants were prepared to explore and invent in creative ways, demonstrating acceptance of the idea and implementation of new technology in the garden.

Overall, challenges observed in the workshop can be framed in terms of *knowledge* issues involved in decisions of **what to plant, where to plant and when to plant**, both general (such as plant sunlight requirements and ph range tolerance) and specific to the environment (how much sunlight is the environment actually getting?). Identification seems to be a problem for the former, as even when resources are available they are difficult to query without being able to identify specific items (such as plants, pests and disease symptoms). Additionally, the adaptability of this knowledge to local conditions is lacking, even once identified. Mapping the (often loosely specified) information in knowledge sources onto coarsely understood local conditions leads to a large solution space and no guidance for exploring it, leading to the main reported decision making strategy of 'trial and error', unguided empirical search of the solution space.

In terms of decision making as situated action, the actor's contingent circumstance does not constrain the possibility space sufficiently for optimal actions to emerge. Supporting more optimal action means constraining the solution space by increasing the availability and specificity of relevant information. One approach would be to increase the availability and specificity of general data (such as plant needs) through identification support and data delivery. Another is to increase the granularity and availability of local environmental state data. The most highly constrained system would direct actors in exactly what to do, or even perform required actions without intervention. However, the workshop observations suggest that this level of direction and automation is not desirable, in line with the findings from the initial interviews conducted in the community gardens.

Unlike in the interviews and literature, there was a lack of evidence for technological rejection in this workshop, although there is a self selection bias in that these participants were specifically interested in using novel technologies in the food growing domain. Similar patterns however were observed - automation and direct instructions were not seen as desirable, whereas advice and decision support was preferred. These findings help to address our RQ1 and inform the first primary contribution of this thesis, *Domain Specific implications for design*. In general, the workshop supports the idea that situated data within the growing space could be useful in supporting decision making whilst encouraging acceptance, adoption and appropriation. It is possible after analysing the design artefacts that an overview type interface would be preferred over distributed interfaces; information would still be present in the growing space, and a tangible design would permit collocated collaboration, however the extremely localised nature of the decision making and the concept of situated action suggests that more situated information placed directly by plants/beds would map better onto practice. The emergence of these multiple levels was unexpected; in the previous interviews, gardeners had stressed the importance of being in the garden and making decisions amongst the plants or areas of interest. Previously, we had been focusing on data situated directly on or near plants. However, the appearance of these different levels led us to consider the difference between *situated* and *overview* interfaces to data in the garden, which is of direct relevance to RQ2. This is important because if we had jumped straight into a long term RITW deployment we would have focused on just the situated aspect of a system, but this workshop added nuance to our understanding of data use in the garden and also to our thinking about situated action as a whole (and thus the second primary contribution of this thesis); its easy to think of just the immediate environment when considering situated action, but actually these 'overview' elements could be an important part of the contingent circumstance. The experiment reported in the next chapter aims to provide more information on this area by contrasting the effects of situated versus overview information on behaviour.

Also in regards to the third study specific research question about adoption: The delight at tea boxes as construction material was evident, as discussed previously. This is not just a materials reuse issue, but also one of 'cuteness'. However, the specific materials used are not practicable in the garden, as they are not weatherproof. Identifying weatherproof enclosures that are easily sourced from household materials and maintain this appropriated-but-cute aesthetic may be an important part of designing for deployment.

As mentioned in the Method section of this chapter, all of the participants were female; this doesn't reflect the observed gender balance at the various communities in the previous study, where there was a skew towards female but males were not completely absent. In general, females and males are more similar than different (Hyde, 2005), and meta analyses tend to show only trivial differences on most psychological measures (Hyde, 2014). However, there are moderate to large effects on a few dimensions such as 'agreeableness' (females tend to score more highly on agreeableness than males) and 'interests in things versus people' (males tend to be more interested in things versus people than females) (*ibid*), which may be relevant in this case of (possible) increased likelihood of attending a workshop. It has been argued that gender differences are not interesting in and of themselves, only in as much as they are diagnostic of gender-biased designs, processes and social structures (Newcombe, Mathason, and Terlecki, 2002; Tzuriel and Egozi, 2010; Hyde, 2014). As such, whilst gender may not be of particular interest to this research in and of itself, the workshop makeup highlights the self-selection bias inherent in this kind of co-design approach in general and in this specific study in particular[2].

Reflecting on how this workshop relates to the RITW framework, we see a strengthening of the idea that there is an **emerging theory**. Performing the workshop reinforced some of the findings we saw in the contextual interviews, and also added nuance to our understanding. Of most note was the importance of the different *situated* and *overview* representations; after the contextual interviews this felt like a subsidiary point, but following the workshop this gained a new level of salience. Again, it felt at this point that the problem area was insufficiently specified to go straight to a full RITW deployment - although the process had helped narrow the focus to *sensor networks* as opposed to *remote sensing*, and identified two areas we could augment (domain knowledge and local environmental knowledge). This led to the thought that the iterative RITW process is about developing this emergent theory in order to constrain the design space for the RITW deployment. Each new activity helps us to answer the question 'what should we build'. Framing RITW in this way allows us to slot research activities into the framework that might otherwise seem inappropriate for RITW, such as lab based studies which are often argued to be of limited value to RITW (Rogers, 2012; Kjeldskov and Skov, 2014). However, if our goal is to constrain the design space *for* a final deployment, we can use

[2]This selection bias may be even more insidious in such participatory, contextual approaches than in lab experiments - the nature of co-design workshops (especially within a specific community) may give the false impression that the context and values of the community are being probed, as opposed to that subset of the community who participates in co-design workshops.

experimental work to help us explore this design space even though we can't translate the results directly into the context (Rogers and Marshall, 2017).

5.6 Conclusion

One of the outcomes of the workshop was the potential for supporting greater availability and granularity of local environmental information, which could in turn provide support in making challenging decisions. In particular, it was found that identifying plants and pests and making decisions such as what to plant, and where are areas that could benefit. Improving the *availability* and *precision* of general information and local conditions could help to support planting and maintenance decisions. Direct instruction or automation of these decisions was not desired; information to support decisions was preferred rather than 'being told what to do'. Importantly, the design artefacts suggested that the participants were not averse to technology in the growing space (and indeed there was some suggestion that rejection of automation may be overstated - one group designed a partly automated system, even though they had previously said this was something they were opposed to).

Materials reuse was seen to be positive. Demos in the invent phase which used found materials elicited positive responses from participants - materials reuse might be a factor in assisting technology uptake. Participants discussed tools for planting guidance based on direct feedback of information within the garden as a major opportunity, and observations in the Discover and Invent phases suggested that situated data within community food growing spaces could be useful in supporting decision making.

The findings also led to the insight that co-located collaboration is a good starting point for considering design augmentation in the garden. Although RQ2 was not specifically targeted in this study, a particular question raised was how would adding situated information or the in-the-garden overview information enhance gardening practice? In order to examine this question, we designed a lab experiment (presented in the next chapter) to help us understand how representing data in these different ways can alter behaviour.

6 Situated vs Overview Data : An experimental study on the effects of situated and overview data on emerging action in dyads.

6.1 Introduction

The findings from the contextual interviews and design workshop (reported in chapter 4 and chapter 5 respectively) suggested that gardeners use both 'situated' and 'overview' artefacts for 'decision making'; participants report decision making as being highly situated, although the existence of overview artefacts in the garden and the importance of overview components in the workshop designs suggest that these overview components also play a role. The study presented in this chapter aims to isolate the *spatial* aspect of these two classes of artefact, and examine if varying this aspect impacts the evolution of action in collaborative tasks.

6.2 Motivation

Growing plants to produce useful harvests (such as food or medicinals) is a complex and knowledge intensive activity, involving many decisions that rely on local environmental data and domain knowledge (Lyle, 2013). We observed in the previous in-situ interviews with community gardeners (chapter 4) that a number of data artefacts are used in community growing environments to provide knowledge support in the garden; seen through the lens of situated action (Suchman, 2007), it could be said that these artefacts shape the emergent action in the garden by altering the contingent circumstance (people's holistic experience of both the world and their internal states, from which situated action emerges). Examining these existing data artefacts can help us not only to design data tools for the garden, but also to explore the emergence of action and how to augment such action in shared spaces more generally.

As discussed in chapter 4, we observed two main types of data artefacts in the garden; *situated* data artefacts (such as markers and signs) which were located in the bed next to the objects or areas to which they referred, and *overview* data artefacts (such as maps) which were in the garden but not in the growing locations, being commonly found in structures such as sheds and greenhouses. The situated and overview data artefacts record similar data, but with a different spatial scope; both types of artefact use a spatial binding for the data, but the situated artefacts directly bind data to the world whereas the overview representations bind data to an abstract representation of the world (namely, a map). It is possible that the different nature of these representations arose simply due to practical task demands or cultural practice, however it is also possible that the different types of data (situated and overview) have affordances that are augmentative of action in different ways. Regardless of the motivation in practice for the existence of these different types of representation, it is possible that the nature of the representations alters the manner in which action emerges in the garden. Action in the garden is emerging in the presence of *both* of these types of supportive data artefacts; indeed, both types of artefact encode similar data about the environment and the plants in that environment, suggesting there is some value in the different representations themselves (as opposed to some data being more suited to particular types of representation).

In order to explore the manner in which these different types of data artefact impact the emergence of action in a shared space (and thus address our overall RQ2), we adopted a mixed methods approach: Firstly, we investigated how the spatiality of these artefacts impacts emergent action, if at all, in a controlled experiment (the study reported in this current chapter), and secondly we examined situated versus overview representations in the garden context using a provocative prototype study (reported in chapter 7). Often in HCI a 'lab' usability study is followed up with a 'field' study in order to examine the system under investigation its context of use, revealing context specific issues and appropriations that are not seen in the lab (Rogers, Connelly, et al., 2007; Brown, Reeves, and Sherwood, 2011). In addition to allowing testing and possibly iteration of a system before committing to resource intensive work 'in the wild' (Rogers, Connelly, et al., 2007), such lab studies make it easier to collect metrics for benchmarking and formal evaluation of a system. In terms of Bryman's taxonomy of motivations for mixed methods (Bryman, 2006)[1], it could be said the primary motivators are *Context*, *Utility* and *Credibility*: the 'wild' work provides contextual understanding to complement the lab studies more generalisable findings, the combination of methods makes the findings more useful and applicable to practitioners, and ultimately the work is perceived as having more credibility by having been evaluated both in a procedural manner in the lab and in a more realistic 'real world' context.

The motivation for using mixed methods in this current experiment is slightly different; we seek to use the different methods to uncover different aspects of situated vs overview data and their effect on the emergence of action. The experiment allows us to examine the specific effects of situated and overview data artefacts purely as a factor of their spatial binding, whereas the provocative prototype study allows us to imagine how the introduction of these types of artefact in the wild could influence the emergence of action in the garden. Taken together, the results help to shape our understanding of situated and overview data on the emergence of action by examining different facets. In Bryman's taxonomy, this approach is primarily motivated by:

[1]Although Bryman's taxonomy of mixed methods doesn't strictly cover multiple levels of mixing *within* methods (and mixing lab and wild research could be seen as an example of nested mixing, combining two already mixed methods), the categories are still broadly applicable and useful here for illustration.

Completeness

that the areas can be more fully explored by using both methods,

Diversity of views

that quantitative work examines relationships between variables whilst qualitative work reveals "meanings among research participants.", and

Different research questions

"...that quantitative and qualitative research can each answer different research questions" (Bryman, 2006).

As such, the experiment reported in the current chapter is designed to narrowly focus on the spatial differences in situated and overview data on the emergence of collaborative action.

6.3 Research Question

This study aimed to address the following study-specific research questions:

1. How does situated versus overview information alter the emergence of action in a spatially based, colocated collaboration activity? This question addresses the high level RQ2 (and is potentially useful in informing RQ1).
    - Does the introduction of *data* change behaviour?
    - Does the *situated* information alter behaviour in a different way to *overview* information?
2. What can we learn from performing this type of experiment that we can use to inform our RITW framework extension? This question addresses RQ3.
    - can we use experiments as part of the framework?
    - how should we design those experiments to fit in the framework?

6.4 Method

In order to address the research question, an experiment was conducted using a room-scale abstract learning task called the Energy Harvesting Task. The Energy Harvesting Task (described in more detail below in subsection 6.4.1) was based on the decision making process of *where and what to plant*, which were identified as core decisions in the contextual interviews and design workshop (reported in chapter 4 and chapter 5 respectively). To prevent possible learning transfer from garden settings (as some amount of gardening and plant care are common activities), the task was not themed as a gardening task, but was abstract. The abstraction and simplification of aspects of *where and what to plant* allows for control and isolation of specific variables, making them amenable to analysis in an experimental setting. In this turn-based task, pairs of participants[2] collaboratively decide where to place tokens each turn, choosing between 6 physical locations distributed around a room. Their choice of placement determines how many points each token scores over the course of the task; over time, as participants learn how the locations and the tokens interact, their token placement changes. By examining the placement of tokens over the course of the task, we can gauge how well pairs are learning the hidden properties of the system, and thus operationalise the emergence of action as a trajectory. Introducing additional situated or overview data artefacts allows us to see how this trajectory is influenced by these types of data - see subsection 6.4.2 for more detail on the experimental design and task manipulations.

6.4.1 Energy Harvesting Task

In order to address the research question, a task was developed that uses hidden system properties which can be uncovered over time by experimentation and observation. This was based on the 'trial and error' strategy

[2]pairs of participants were used rather than individuals, as participants in the contextual interviews emphasised the collaborative nature of 'decision making' in the garden

that the interviews (see chapter 4) and workshop (see chapter 5) suggest that growers use in the absence of concrete supporting information. The presentation of hidden information can then be used to create experimental manipulations (expanded on in subsection 6.4.2). The task is designed to be completed in around 30–45 minutes; this gives enough time for patterns to emerge and change over time (Rogers, Lim, et al., 2009), and permits the total session length to be around 1 hour to avoid fatigue effects in participants, and to make recruitment and room booking easier[3].

The Energy Harvesting Task was abstracted from the decision making process of *where and what to plant*. ‘Where’ was abstracted into 6 discrete locations, and ‘what’ into a choice of 2 types of token. To avoid learning transfer and thus potential confounds, the task was not themed as a gardening task. Rather, participants were tasked with ‘getting energy’ into each token to score points. Placing tokens onto locations allowed that token to accumulate energy from the location, and when enough energy had been accumulated, a point counter was placed on the token. The goal of the task is to score as many points as possible by the end of the task, and to do this successfully participants had to identify which locations yielded the most points for each type of token.

Each turn, pairs received 4 objects called ‘tokens’ (Figure 6.1). These were 5cm x 5cm white foamcore tiles, with either a black circle or black triangle marked on them - these abstract geometrical shapes were chosen so to minimally bias participants, but to retain distinctiveness. The white/ black balance of the two shapes is similar, and they are perceived to cover a similar area (i.e., one does not look larger than the other). Pairs received 2 circle and 2 triangle tokens each turn, and had to place the tokens on one of the six set locations (called ‘energy patches’) around the room (see Figure 6.1). The energy patches were white index cards, capable of holding up to 9 of the tokens without stacking. Participants could place tokens on any of the six energy patches, and there was no restriction on the number of

[3]Particularly important for room-scale experiments which have limited flexibility in terms of where they can be conducted.

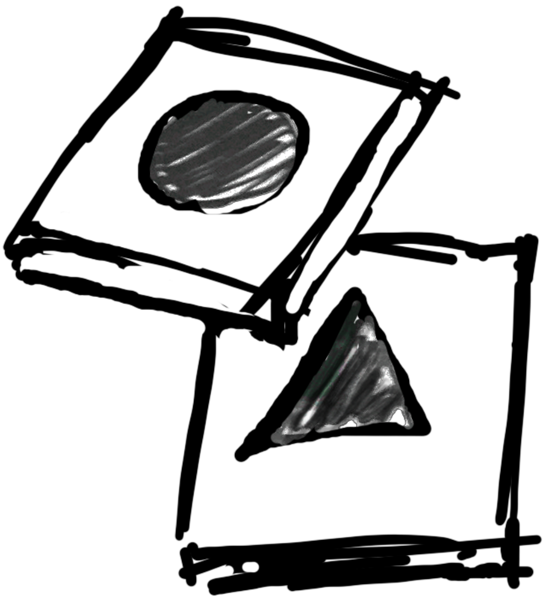

Figure 6.1: The two types of tokens used in the Energy Harvesting Task. The abstract geometrical shapes were selected to maintain distinctiveness, without biasing participants

tokens that could be placed on a single patch. The participants, however, had to place all their tokens before they could proceed to the next turn. Tokens had a lifespan of 3 turns, after which they were removed and the points on them were added to the pair's score. This lifespan was based on the cyclical nature of planting decisions, as pairs did not immediately see the full outcome of their decisions.

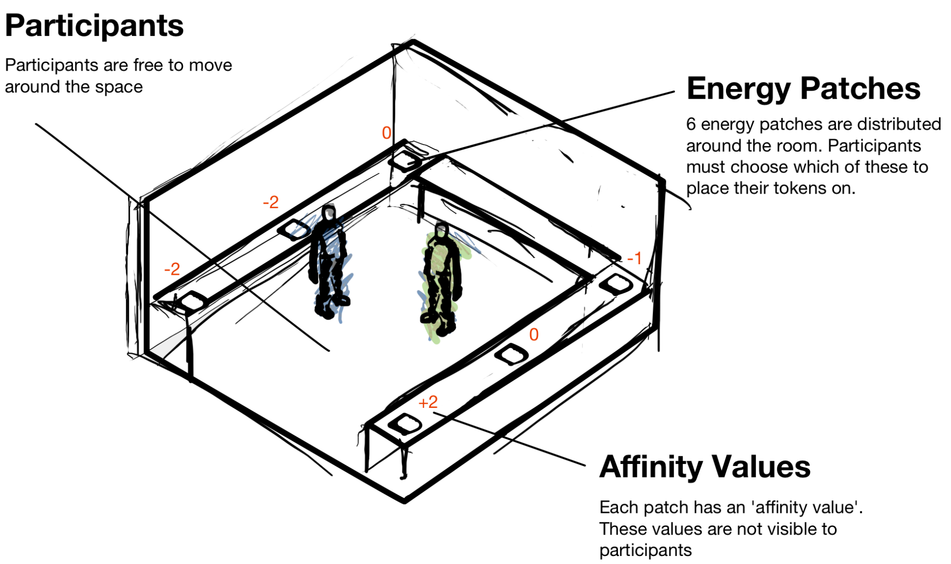

Figure 6.2: Room layout for the Energy Harvesting Task

Each of the energy patches had a value associated with it (called 'affinity' in this task) which was time invariant, and constant within the experiment. This value was broadly based on soil ph, the spectrum of acidity to alkalinity of soil. Certain plants prefer different ph ranges - some for instance will thrive in acidic soil and die in alkali, and vice versa. In this task, affinity ranged from –2 to 2, and each patch was assigned one of the integers on this spectrum (–2,–1,0,0,1,2) - There were 2 zero patches in order to fully balance locations and information displays). Triangle tokens gained more ‘energy’ on positive affinity patches, and circle tokens gained more ‘energy’ on negative affinity patches. Thus, to maximise their points, pairs should place triangles on high positive affinity patches (such as +2), and circles on low negative affinity patches (such as –2) - see Figure 6.3 for an example)

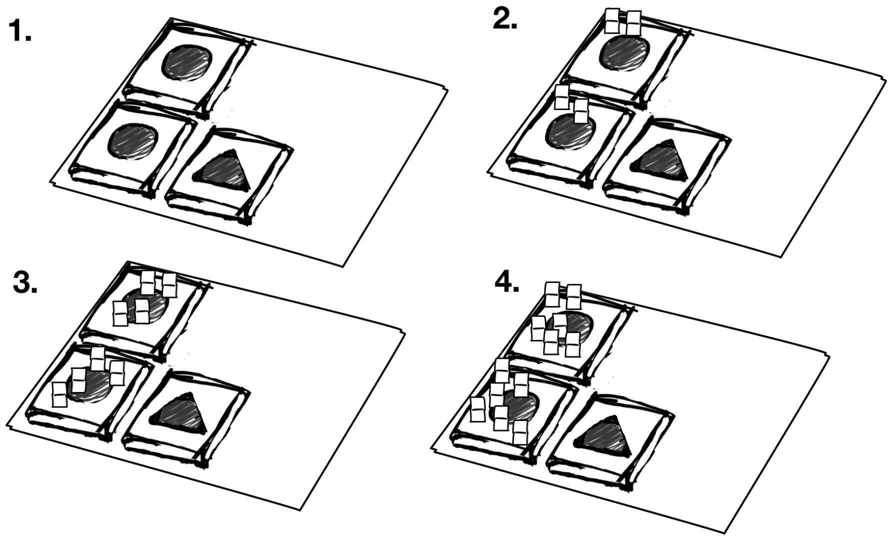

Figure 6.3: Points placement over time on a –2 affinity energy patch. 1: The pair has just placed two circles and a triangle. 2: Points are placed on tokens at the end of the turn - the –2 affinity of the patch means the circles score the full 2 points an the triangle scores 0 points. 3: The end of turn 2; circles score two more points each. 4: The end of the third turn - after this turn, these tokens will be removed and their points added to the pair’s total.

This system was chosen as it is the simplest type of hidden value (being time invariant), and understanding the system requires knowledge of two variables object type and patch affinity, and the relationship between object type and affinity, allowing the display of hidden information (affinity) along with the always visible information (token type) whilst still requiring exploration of the system to understand the underlying relationship. This allows access to two methods of approaching the problem, simple hill climbing where pairs experiment until high scoring patches are located, and stick to them, and system understanding where pairs try to ascertain the underlying relationship between the different token types and the different locations.

The score for each token each turn was calculated using the following equation:

$$\text{score} = \text{t} \times (\text{base} + \text{affinity} \times (\text{energy} \times \text{modifier}))$$

where **t** = elapsed turns since token placed, **base** = 1, **modifier** = 0.5, and **affinity** = 1 for triangle, –1 for circle.

This gives total score outputs over a token's lifecycle ranging from 0 for a 'worst' placement to 6 for a 'best' placement, with an interval of 1.5 between each level of score. Initial testing of the task with pilot participants showed that this regular structure was too easy to work out - as such, in the final version of the task, points tokens were only placed when participants had accumulated a full point, meaning the score seen by participants was actually:

$$\text{score} = \left\lfloor \text{t} \times (\text{base} + \text{affinity} \times (\text{energy} \times \text{modifier})) \right\rfloor$$

This rounding down was introduced to obfuscate the relationship between affinity and score, which increased the challenge of the task.

With these final scoring rules, this means that a triangle on a +2 patch (the 'best' placement possible) received 2 score counters on its first turn, 2 counters on its second and 2 on its final turn, for a total of six. A triangle on a +1 patch (good placement, but not optimal) received 1 score counter on its first turn, 2 on its second turn, and one on its last turn for a total of 4. On a 0 patch (neutral placement), the triangle would get its base amount only, 1 per turn, and on a –1 (bad placement) it would get 0, 1, 0, and a on a –2 (worst placement) it would score no points each turn. This means that in any particular turn, the highest score a pair can get is 8 points *from tokens placed that turn.* Tokens from previous turns continue to score points, but because of the nature of the scoring system we already know from a tokens placement what its lifetime total points will be (although the participants do not, at least initially) - this can be seen in Table 6.1.

Table 6.1: Table of task scoring structure

Token Type	**Energy Patch**	**Placement**	**Turn 1**	**Turn 2**	**Turn 3**	**Total**
Triangle	2	Best	2	2	2	6
Circle	2	Worst	0	0	0	0
Triangle	1	Good	1	2	1	4
Circle	1	Bad	0	1	0	1
Triangle	0	Neutral	1	1	1	3
Circle	0	Neutral	1	1	1	3
Triangle	-1	Bad	0	1	0	1
Circle	-1	Good	1	2	1	4
Triangle	-2	Worst	0	0	0	0
Circle	-2	Best	2	2	2	6

A short description from one of the pilot sessions is related here to help get an idea of how the task proceeds (see Figure 6.4) for a schematic representation) :

1. It is P1 and P2's 1st turn. They have 2 circle tokens and 2 triangle tokens. They decide to place a triangle and a circle on the bottom left patch, and the remaining triangle and circle on the bottom right patch. The bottom left patch has an affinity of –2 and the bottom right +1 in this instance. They therefore get no point counters on

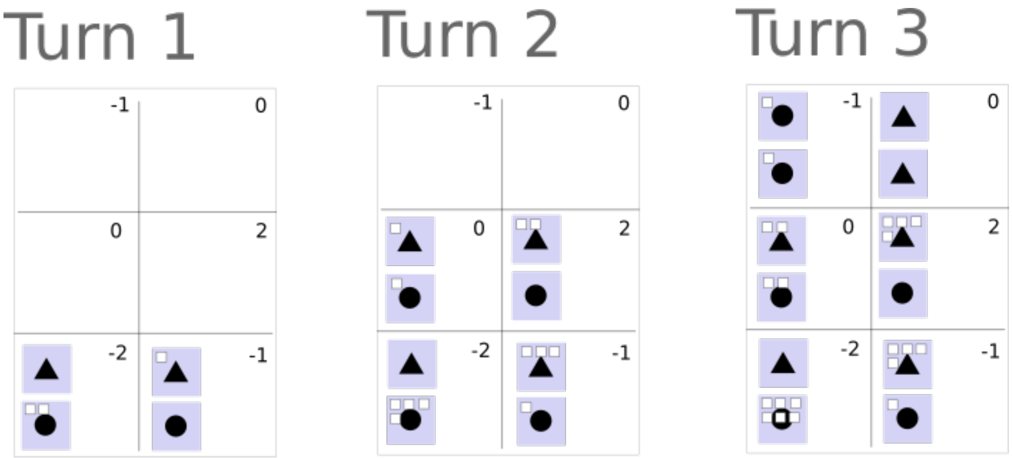

Figure 6.4: First three turns of a pilot Session

the bottom left triangle, 2 point counters on the bottom left circle, and 1 point counter on the bottom right triangle.

2. It is P1 and P2's 2nd turn. They receive a new set of tokens, and place a circle and triangle on the left middle, and right middle patches. These have 0 and +2 affinity respectively, so at the end of this turn the experimenter places 1 point counter on each token on the left mid, and two counters on the right mid triangle. The experimenter also adds another 2 counters to the bottom left circle, 2 to the bottom right triangle and 1 on the bottom right circle.

3. Turn 3. P1 and P2 receive another new set of tokens, and decide to place two circles on top left, and two triangles on the top right as they want to see if matching the same types has any effect. The top left patch has −1 affinity, and the top right has 0. At the end of this turn, the experimenter places 1 point counter on each circle in the top left, 1 on each triangle on the top right, another 1 on each token in the middle left, another 2 counters on the triangle in the middle right, 2 more counters on the triangle in the bottom left and 1 more counter on the bottom right triangle. After giving the pair time to examine and discuss, the experimenter removes the tokens placed on the first turn (which are all on the bottom left and bottom

right), and marks down the points they scored (6 for the circle in the bottom left, 0 for the triangle in the bottom left, 4 for the triangle in the bottom right and 1 for the circle in the bottom right).

4. Turn four - from this point on, the pair always placed all their circles on the bottom left, and all their triangles on the mid right, which was the optimum placement in their layout.

6.4.2 Experimental Design and Task Manipulations

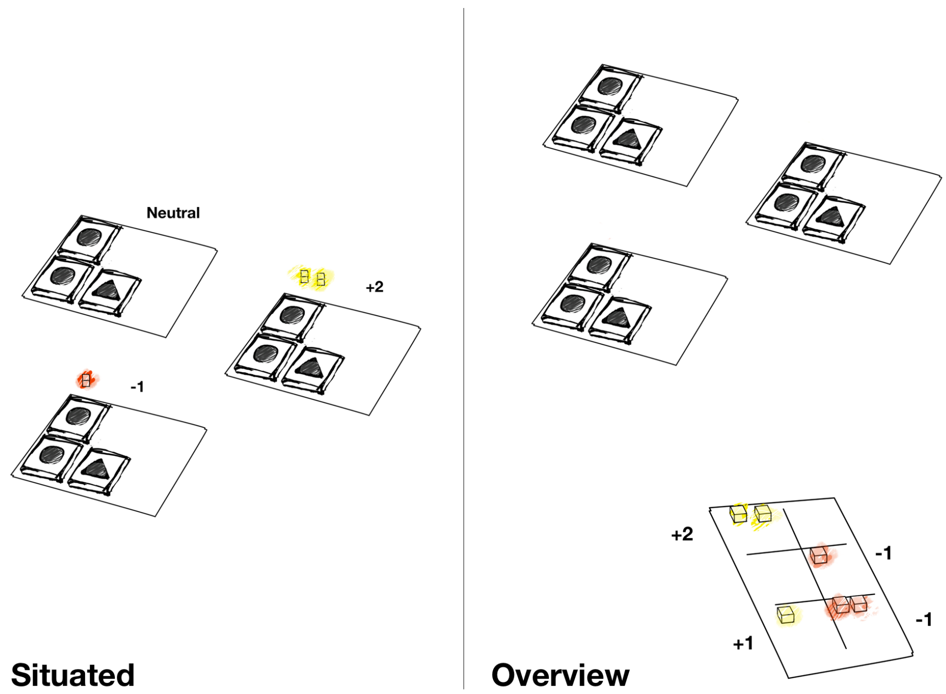

Figure 6.5: Each coloured cube represents one unit of affinity. Note how in the Situated condition, the cubes are next to their patch - in the Overview condition, they are attached to a schematic representation that pairs can hold. The cubes are identical, it is only their placement that varies between conditions.

The experiment had 1 independent factor of *information* with 3 levels, *control*, *situated* and *overview*. In the control condition, pairs do not receive any additional information apart from the results of their actions.

Participants in the *situated* and *overview* condition receive additional information about the affinity of the energy patches, although they are not informed of the meaning or significance of the data. Participants in situated and overview conditions receive exactly the same information, using exactly the same representation. However, the *location* of the information is different; the situated information is directly associated with its patch whereas the overview information is provided all in one place which is not physically linked to the patches.

In both conditions, affinity data was presented using coloured centimetre square cubes. The different colours represented the different sign of the affinity (negative or positive), and the number of cubes represented the magnitude. Which colour maps to which sign was counterbalanced in the experiments, but for simplicity all examples in this chapter use yellow as positive and red as negative. In the situated condition, the cubes were placed directly next to their relevant energy patch, whereas in the overview condition, the cubes were attached to a card with 6 sections that corresponded to the locations of the 6 energy patches (seeFigure 6.5 and Figure 6.6). Cubes were selected as a representation medium as they allowed for a very simple representation that was a direct magnitude mapping, with stability of representation across the two conditions.

6.4.3 Hypotheses

It was hypothesised that *situated data* would lead to better performance on the task than *overview data* and *no data*. This hypothesis was based on an emerging theory about data in the garden; participants in the contextual studies reported that decision making was done in situ, collaboratively and in an ad-hoc manner. The prevalence of situated artefacts and the situated nature of the designs in the workshop also suggested that these kind of situated representations might support decision making in the garden, meshing well with the idea of situated action.

More formally, the model comparisons (described in more detail in the

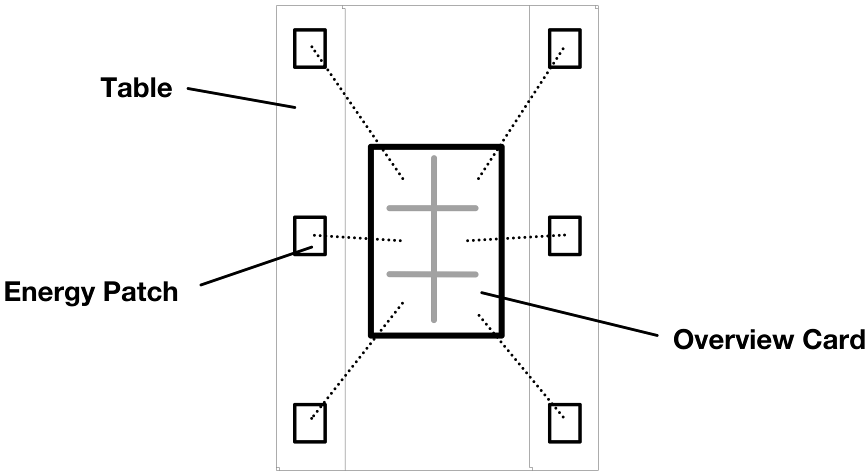

Figure 6.6: The dotted lines show the correspondence between each section of the overview card and the areas of the room. This diagram is not to scale, obviously! It was initially thought that participants might struggle with getting the orientation confused, but this was not observed in the pilot or experiment proper.

Results and Analysis section) tested if there was a *difference in change over time* across the three conditions. The null hypotheses tested by the models were: 1. there is no difference in the value of token placement per turn over time - in other words that participants do not learn at all over the course of the task. 2. there is no difference between the conditions in the change in the value of token placement per turn over time - in other words, the different conditions do not change the participants learning of the task.

6.4.4 Participants

Pairs of participants were recruited using opportunity and snowball sampling via social media, and a recruitment information page[4] was disseminated via social media networks. Dyads were used rather than larger groups due to the difficulty of recruiting sufficient numbers of larger sets of participants (Rogers, Lim, et al., 2009).

15 pairs of 2 participants (30 in total) were recruited, and each pair was randomly assigned to a condition (situated, overview or control(Table 6.2)), giving 5 pairs per condition, as per (Rogers, Lim, et al., 2009). All participants were professionals or research students, educated to at least undergraduate level and spoke English natively or fluently. Participants all lived and worked in London, and represented a number of nationalities including English, Welsh, Scottish, Indian, Argentinian, Turkish and Chinese, with the single largest national grouping being English. No participants had previous experience in community gardening, (in order to avoid learning transfer), and the participants making up each pair were previously acquainted with the other participant in their pair.

Previously acquainted participants were chosen for two reasons: the first is that community gardeners tend to have existing relationships, and even for new or infrequently attending community members, there is an implicit common purpose and friendly social framing. The second reason was that

[4]https://cenau.github.io/participate/

two of the pairs in the pilot study were not previously acquainted, and their performance was worse than the pairs with existing relationships: they interacted with each other less and collaborated less. It seemed possible that this could mask effects of the experimental manipulation and as such it was decided to focus only on pairs with an existing relationship for the study proper. Pair 14 were excluded from further analysis, as they were the only group that failed to reach the 'optimum' placement by the end of the study, and their points total was a clear outlier, being 12 standard deviations below the mean.

Table 6.2: Table of participants

Condition	**Pair**
Control	0, 3, 6, 9, 12
Situated	1, 4, 7, 10, 13
Overview	2, 5, 8, 11, 14

6.4.5 Procedure

The experiment was conducted in a room sized approximately 5 metres by 5 metres, with a counter at around waist to elbow height running around three sides of the wall (Figure 5.2). Participants were told that they were free to move around the space. All sessions were audio recorded, however due to equipment failure there was no recording for the second session.

Each 60 minute session was preceded by a participant briefing and consent form signing. Participants were informed that the study was about a task that they would work on together, and that the sessions would be recorded for later analysis. Participants were also informed that they could withdraw their data at any time. Participants then read and signed the consent form, and the experimenter began the recording.

Following this briefing, the session began with a five minute instruction presentation. The task instructions were given orally, and a written reference provided. Participants were instructed that they could ask questions at any time, but that the experimenter might answer that they would tell them at the end. Common questions included: *"how many tokens can we put on each patch?"* and confirmation that *"we have to put all out tokens down every turn?"*. Some participants also asked at the end if they could find out how well they had done compared to other pairs. While giving instructions, the experimenter set up the energy harvesting task in the room. 6 index cards (energy patches) were placed by the experimenter around the tables at the edge of the room, as spatially separated as possible, ensuring there was at least a 1m separation between each patch. (Pilot studies had shown that lower scales of separation, such as at a large tabletop scope, were insufficient to give a true distinction between overview and situated conditions; the lack of spatial separation effectively made the task model a large interactive surface rather than a situated environment). 3 of the energy patches had positive affinity and 3 had negative affinity, as described in the Energy Harvesting Task section above (subsection 6.4.1). Each set of 3 had one neutral card (0 affinity), one weak (1 affinty) and one strong (2 affinity). Affinity locations were assigned at random from the total set of possible permutations. Once a permutation had been used, it was removed from the set for future experiments. At this point, the experimenter's next action depended on which condition had been assigned. In the control condition, the experimenter performed no additional setup steps. In the situated condition, the experimenter distributed cubes to indicate affinity next to each patch. In the overview condition the experimenter gave the participants the overview card with cubes attached. In both experimental conditions, the participants were informed the cubes would tell them something useful about the task, but were not told what they meant. The experimenter was present in the room the entire time, moving to an unobtrusive part of the room as the participants moved around.

The Energy Harvesting Task was administered immediately to participants following this setup phase.

1. Each turn, the participants were given 4 tokens (2 circle, 2 triangle). Pairs had to place all their tokens on 'energy patches' (index cards). They could place as many or as few as they wished on each patch, but they had to have no tokens left over in order to progress. Once the participants had placed a token, they could not move it for the rest of the experiment.
2. At the end of each turn, the tokens 'drew' energy from the patches they were placed on. When a token had gained enough energy, it acquired a point counter. The number of counters at the end of the experiment determined the pairs score. The indirect relationship between energy and points added ambiguity to the system, reflecting the influence of variables on outcome rather than direct coupling. Additionally, it increased the challenge of the task.
3. Tokens only lasted for 3 turns, after which their score was recorded and the tokens were removed.
4. Tokens on a patch with neutral affinity (i.e., a triangle on a 0 affinity patch) get their basic energy rate. Tokens on a patch with matching affinity (i.e., a triangle on a +1 or +2 patch) get a bonus. Tokens on a patch with opposing affinity (e, a triangle on a –1 or –2) get a penalty - in the case of strong (2) affinity, this penalty means the token gets no energy. Points are given for each full energy point, and point counters are physically placed on the tokens that scored those points by the experimenter.

It was hypothesised that over time, participants should begin to understand some aspects of this system, and tend towards the optimal strategy - putting all circle tokens on –2 and all triangle tokens on +2.

There were 9 turns before the task ends; this number was determined in pilot testing to be sufficient for all pairs to achieve a stable optimum strategy.

The placement of tokens on each turn was recorded using preprepared fieldsheets. Notes and observations were made where possible.

6.5 Results and Analysis

It was hypothesised that *situated data* would lead to better performance on the task than *overview data* and *no data*. In fact, we found no significant difference in overall performance between the conditions. However, there was a significant interaction between the conditions and the turn of the experiment - situated and overview data led to different types of behaviour, rather than one performing more optimally than the other, overall.

6.5.1 Analysis Approach

Pairs' only way to effect the system was in their placement of tokens. As such, considering *token placement over time* allows the examination of action emerging within pairs. As discussed earlier in subsection 6.4.1, the linear mathematical relationship between points and placement over a tokens full 'life' of three turns means the total points scored on tokens placed in a particular turn gives the lifecycle 'quality' of the placements in that turn - a full 8 points (2 for each token) represents the best possible placement, 0 points represents the worst possible placement. As such, examining the change in trajectory of 'points on tokens placed this turn' allows us to chart the development of pairs' action over time.

A model comparison approach (Judd, McClelland, and Ryan, 2011; Maxwell and Delaney, 2004) was used to analyse this data, as it allows both the within-pair (over time) and between-pair (such as introduced by the condition manipulation) changes to be addressed simultaneously (Singer and J. B. Willett, 2003). Linear Mixed Effects (LME) models were constructed with points on tokens as the dependent variable, condition and turn as fixed effects and pair as a random effect. LME was used as we cannot treat pairs as a fixed effect given that they are a sample of the total population, but effects over time *are* fixed for each pair and within each condition. Maximum Likelihood (ML) estimation was used as Restricted Maximum Likelihood estimation (REML) is unsuitable for comparing models with different number of fixed effect terms (Singer and J. B. Willett, 2003) (Pinheiro et al., 2015). As such, tests within models were sigma adjusted to give REML-like results (as this is more conservative) (Pinheiro et al., 2015).

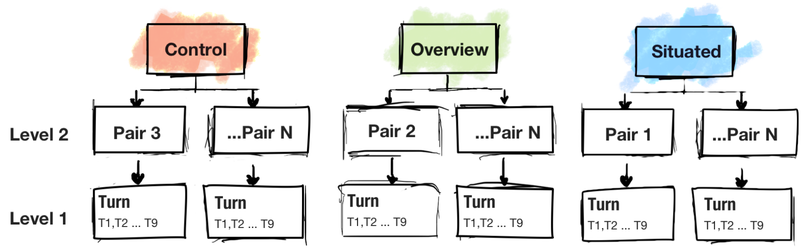

Figure 6.7: Multilevel model figure. Each turn is nested in a pair, and each pair is nested in a condition.

Multilevel modelling for change over time uses two sub models - a 'level–1' submodel that describes the change over time for each individual (each dyad in this experiment), and a 'level–2' submodel that describes how the differences in change *between* individuals (again, dyads in this experiment) are associated with predictors, such as experimental condition (Singer and J. B. Willett, 2003) (see Figure 6.7). First, we selected an appropriate model for the level–1 individual growth, then applied a level–2 model to investigate the effects of predictor variables. Following Singer and J. B. Willett (2003), we first examined the data 'in the whole' using empiric graph plots, nonparametric smooths and naive regressions for each pair, allowing us to reason about the data and select a suitable level–1 submodel. We then tested two candidate level–1 sub models (simple linear and quartic) to see which was most appropriate, and combined the quartic level–1 submodel with the level–2 submodel to test if the experimental condition had an effect.

6.5.2 Exploring the data

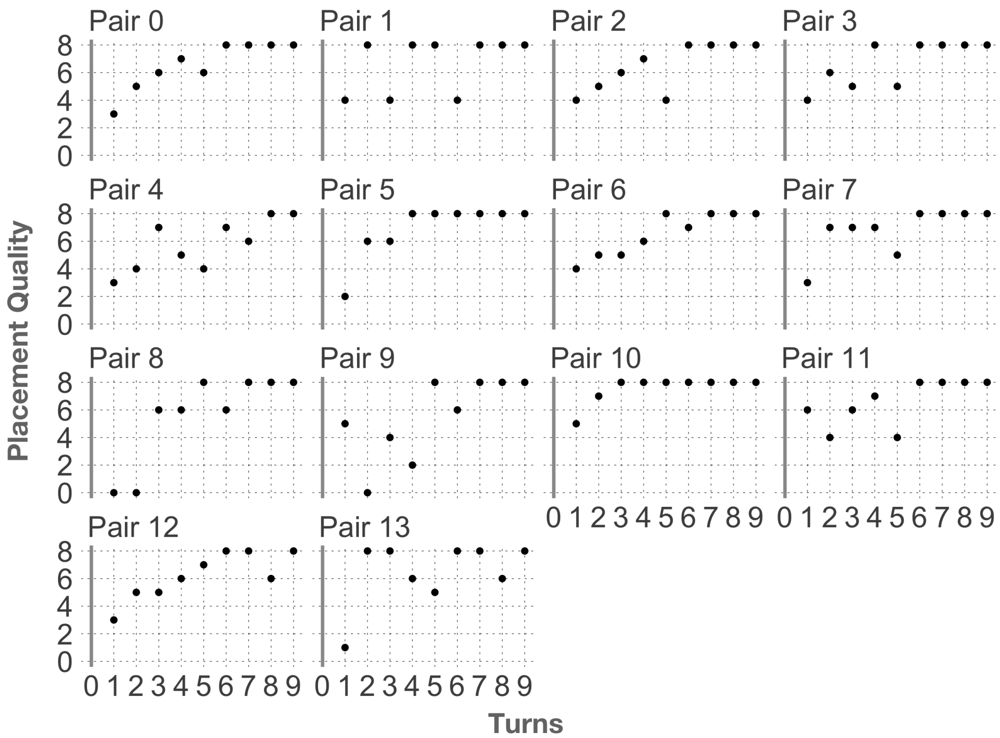

Figure 6.8: Empiric Graph plots of points on tokens placed this turn for each turn for each pair. The left axis shows points, the bottom axis shows turns. The higher the points, the better the quality of the token placement; this graph shows that all pairs improve in the quality of this placement over time, but that some pairs oscillate much more between good and less-good placements (see Pair 1 for instance)

In order to fit appropriate models, we first examine the data with an eye to patterns and possible models (Singer and J. B. Willett, 2003). We begin with empiric plots that only show the results without the conditions, as Singer and J. B. Willett (2003) argue that this helps prevent the researcher imposing false patterns on the data from preconceptions about the conditions. We can see from the empiric plot Figure 6.8 that all pairs show 'improving' trajectories with pairs making better placements over time, and with all pairs reaching a stable selection of the optimum placement by the last few turns of the task. We can also see that Pairs 1, 3, 7 and to some extent Pair 4 appear to exhibit oscillation in the mid to late turns. This behaviour is most prominent in Pair 1 - this pair discovered the optimum solution on the second turn, but then continued to explore the solution space. During the study, this pair reported specifically wanting to understand the system, rather than just score points. They also felt there might be a 'hidden' combination of tokens that would lead to even greater points. Some pairs show clear progression to the asymptote, with Pair 10 describing the 'ideal' trajectory. Pairs 0,5, and 2 also show this curve, although less rapidly and cleanly. Pair 10 took a very analytic approach to the task, carefully planning out each action before they took it, and discussing how they could best use their resources to probe the system - this level of analytic approach was uncommon.

The nonparametric smooth plots Figure 6.9 (using locally weighted regression) confirm these broad features of oscillation for 1,3,7, and 4, and logistic-growth-like curves for Pairs 10,0, and 5. The deviation in the curves of Pair 2 seems likely to be random error rather than truly being double peaked, and Pair 1's true fit is likely much 'spikier'. Collecting the nonparametric smooth plots by condition Figure 6.10 shows that the oscillating pairs fall mostly into the situated condition, suggesting that this difference in observed behaviour is a result of the condition as opposed to some other confounding grouping or variable present in the sample.

The prevalence of double peaks suggest a quartic polynomial fit, however higher order polynomials can be difficult to interpret and are susceptible to overfitting - (Singer and J. B. Willett, 2003) suggest attempting Ordinary Least Squares regression as a level- 1 submodel first, as it is more parsimonious. The nature of the task is such that it might be expected to follow a nonlinear logistic growth model (an S shaped curve); the task has fixed lower and upper asymptotes as participants must score between 0 and 8, and many similar cognitive tasks show this nonlinear logistic growth model (Singer and J. B. Willett, 2003). However, although a good fit for some participants (Pair 10 for instance), a logistic growth model is unlikely to capture the oscillations observed in many pairs. As such, it appears sensible to attempt to fit both a parsimonious linear level–1 model and a quartic level–1 model that may more accurately describe the data.

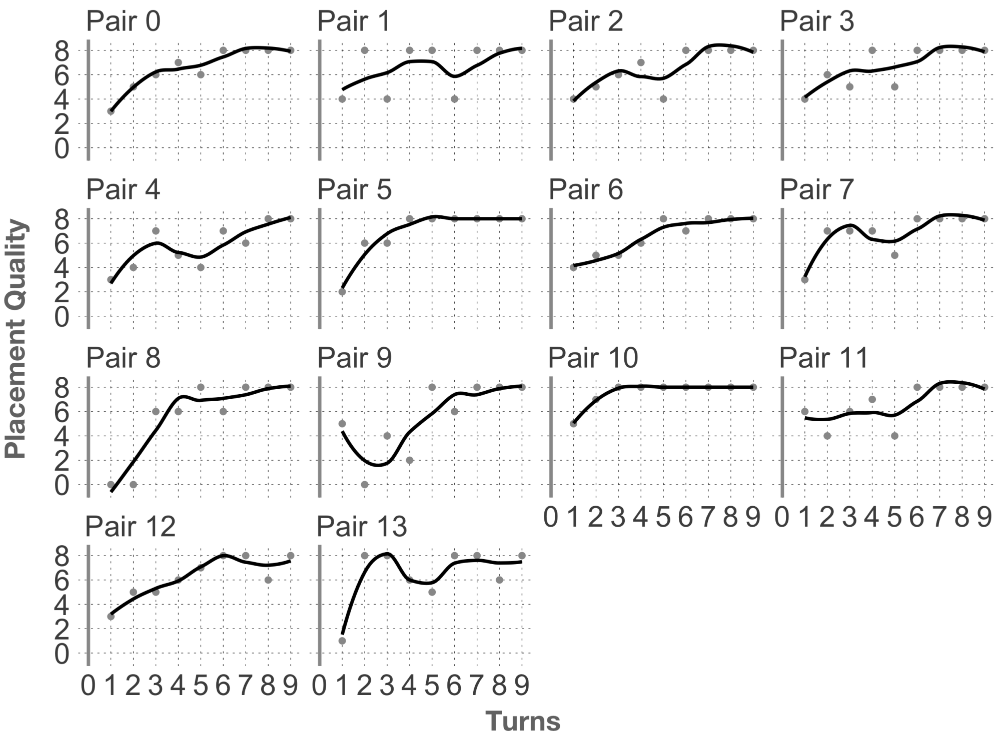

Figure 6.9: Nonparametric smooth (locally weighted regression, specifically loess) plots of points on tokens placed this turn for each turn for each pair. As in the previous figure, the left axis shows points, the bottom axis shows turns.

6.5.3 Model fitting and statistical tests

Singer and J. B. Willett (2003) describe a progression of models that should be fitted; Unconditional mean (there is no change over time, and no effect of experimental condition), unconditional growth (level–1 submmodel, there is change over time) and conditional growth (level–1 and level–2 submodels, there is change over time and it is effected by condition). We fitted these models for both the linear and quartic level–1 submodels:

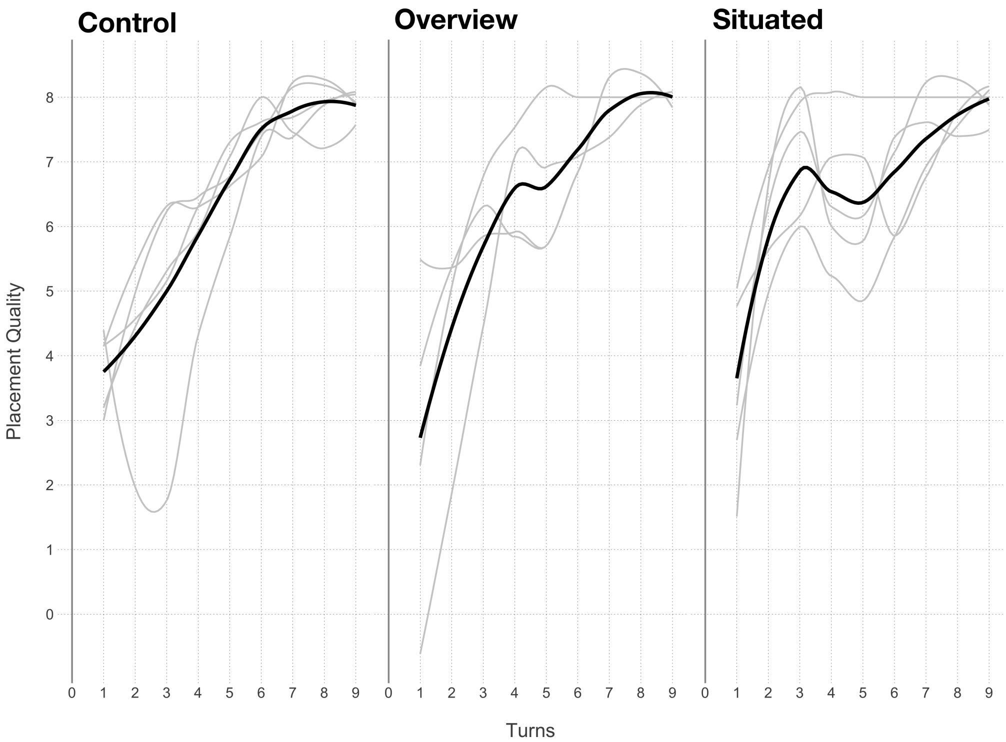

Figure 6.10: The nonparametric smooth plots from the previous figure, collected by condition. Thin lines represent each pair, the thick lines the condition mean. Note the clear initial peak in the situated condition.

Model A : Unconditional mean model

This model represents the null hypothesis that there is no change in behaviour over time, and that there is no effect of experimental condition on this behaviour.

The level–1 part of the model posits that each pair's trajectory is completely flat - they score the same number of points every turn. The level–2 part posits that the average of all the pairs scores is the grand mean - in other words, there is no effect of any experimental conditions.

Model B : Unconditional growth model - linear

This model represents the hypothesis that there is change in behaviour over time, but that there is no effect of experimental condition on this behaviour. Comparing this model to model A tests if behaviour is changing over turns. We would expect this to be the case based on the graphs.

Model C : Conditional growth model - linear

This model represents the hypothesis that there is change in behaviour over time, and that there is an effect of experimental condition on this behaviour. Comparing this model to model B tests if the trajectory of growth is effected by the data condition.

Model D : Unconditional growth model - quartic

This model represents the hypothesis that there is a nonlinear change in behaviour over time, and that there is an effect of experimental condition on this behaviour. Comparing this model against Model B tests if the trajectory of growth is better described as nonlinear.

Model E : Conditional growth model - quartic

This model represents the hypothesis that there is a nonlinear change in behaviour over time, and that there is an effect of experimental condition on this behaviour. Comparing this model against Model D tests if the trajectory of growth is better described as nonlinear.

Model B has a much lower Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) than Model A, indicating a better fit to the data. AIC and BIC are estimates of model quality - the lower the score, the 'better' the model. Log-likelihood ratio tests indicate this fit is significantly better for the data than the unconditional mean model ($\Lambda(3) = 82.547$, $p < 0.001$). This suggests that points on tokens have a relationship with turns, and the parameter estimates show that 0.53 (se = 0.06) more points are scored each turn; pairs get better the more turns they play.

Model C has a higher AIC and BIC than Model B, and is not a significantly better fit ($\Lambda(4) = 3.59$, $p = 0.464$), suggesting that there is no effect of condition. However, Model D has a lower AIC and BIC than Model B, and is a significantly better fit ($\Lambda(3) = 15.01$, $p < 0.01$), suggesting that participants growth is nonlinear, and that a quartic fit may be appropriate for the level–1 submodel.

Model E (Figure 6.11) has a lower AIC but a higher BIC than Model D, and is a significantly better fit ($\Lambda(10) = 18.88$, $p < 0.05$). BIC penalises more complex models (and thus interactions) more harshly than AIC. Given the significant log likelihood test and lower AIC it seems likely that BIC is overly conservative in this instance. However, at this point it seems that the extra complexity of adding new terms would likely outweigh improvements in fit (unless the new terms accounted for a lot of variance), thus leading to the selection of Model E as a good fit candidate. As such, we can argue that the different information conditions are altering behaviour over the course of the task. To confirm this, sequential (type 2 SS) F tests were performed on Model E, sigma adjusted to provide more conservative REML like results (as Maximum Likelihood estimates were used to enable the model comparison). The main effect of condition is not significant ($F(2,16) = 0.58$, $p = 0.57$), the main effect of turn is significant

(F(4,53)=32.61, $p < 0.001$), and the interaction between condition and turn is significant ($F(8,53) = 2.536$, $p < 0.05$). The parameter estimates suggest that the majority of the difference is accounted for by differences between the situated condition and the control condition, although some of the overview-control condition terms are nearing significance.

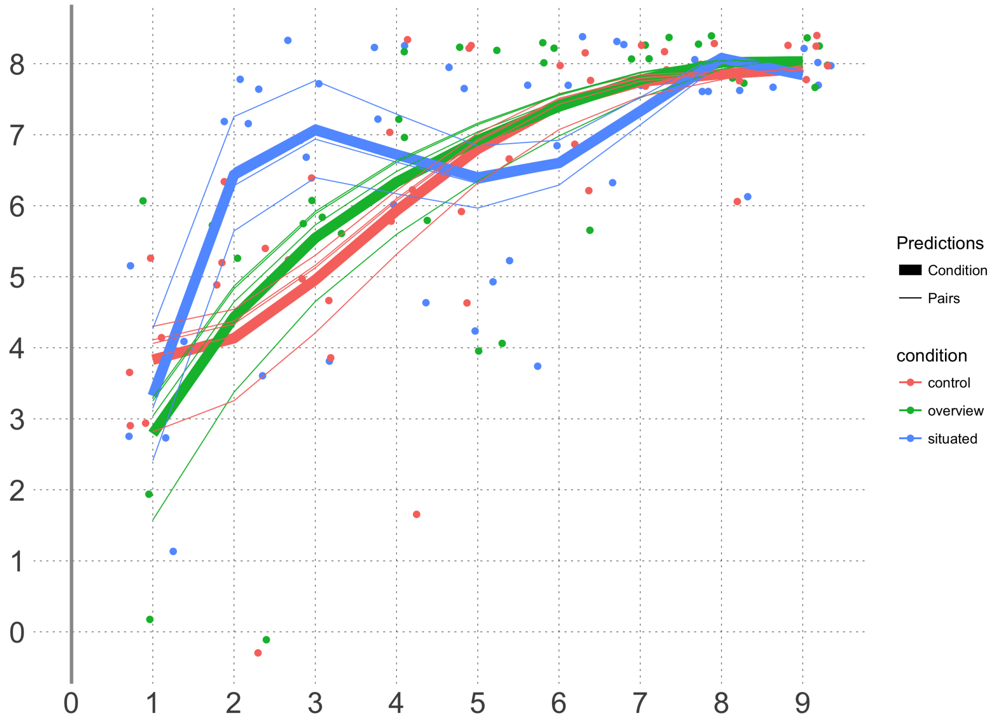

Figure 6.11: Model E - Conditional Growth Model (with Quartic growth). The left axis shows points, the bottom axis shows turns. The large lines show the modelled means for each condition, and the smaller lines show individual (per dyad) modelled means. Points are jittered for legibility due to overplotting of points. The situated condition seems to initially grow faster than the other conditions, before slowing then speeding up again at the end of the task.

6.5.4 Summary of results

In summary, the model comparison results suggest that although the condition does not have a simple main effect on overall performance, with all conditions making higher scoring placements over time and converging on the optimum placements, behaviour over the course of the task *is* different in different conditions. It appears that participants in the situated condition spend more time oscillating in the middle turns, suggesting more exploratory behaviour after they have identified high scoring patches. This strategy is not optimal in terms of achieving high scores on the task in question, however this kind of behaviour may lead to greater success in more complex tasks. The alteration of strategy is particularly interesting as it suggests that situated information is not providing a quantitative boost to performance on the task, but rather is qualitatively altering the approach to the task.

6.6 Discussion

We can see from the results that situated data appears to lead to faster increase in scores in the first few turns, with a slowing of score growth over the rest of the turns. The empiric growth plots suggests that pairs in the situated condition were oscillating between ideal placements and non ideal placements; along with qualitative reports from the participants, this suggests it is possible that the situated data led participants to seek to understand the system, whereas the overview data and no-data conditions led them to strategise for the most points. It is thus possible to speculate that the difference between situated and overview data in the garden is not simply one of convenience or practice; at least in this experimental setup, the situated data appears to affect the behaviour of pairs on spatial learning tasks in a way that overview data does not.

The possible switch of behaviour away from satisficing to seeking system understanding may not be most optimal *for the task at hand* but it may mean that action is more closely coupled to the true contingent circumstance; possibly a more granular understanding is being acquired, leading to a potential for better informed decisions in future. As such, more complex tasks where understanding the system is more important for success might show performance gains in the situated condition. It is not immediately clear what impact this altering in solution search strategy will have in the wild. Speculatively, the switch into a more understanding seeking approach may lead to better holistic understanding of the growing space and improved collaboration through increased inquiry. It is also possible that the initial outcomes may be *negative* as the encouragement to greater exploration leads to moving away from a local optimum, but leads to long term benefit by locating new, higher energy optima.

Since the representation in the situated condition is informationally equivalent to the overview information, it can be argued that it is the situated nature of the information, not just extra information, that is behind this difference in behaviour. It could also be argued however that the information itself is not having an effect, just the appearance of extra information; it is possible that the presence of situated information signals that there is some kind of complexity or structure, leading to increased understanding-seeking. However, the parameter estimates in Model E suggest that participants in the situated condition perform better in the early part of the task (Figure 6.11) than other conditions - making better decisions before the pairs have had an opportunity to search the space suggests that they *are* gaining and integrating informational content from the situated information in a way they are not from the overview information. One question is whether the difference in mid and late task behaviour is not due to situated information *per se* but to starting with *better initial placements* - if situated data simply provides a boost to initial selection, it is possible that the exploratory behaviour is driven by early success; for instance, participants may be seeking system understanding because of a belief that there must be a 'harder' or 'hidden' level that hasn't been discovered yet. It is also possible that the overview data was simply not used; in the situated condition, participants do not need to make a special effort to access data about a patch they are examining or interacting with - the overview data is not available as a 'side effect' of performing the task in the same way and it could be argued that the cost of accessing the overview data is higher.

However, the change over time for overview data being different to the control condition is trending towards significance in Model E - it may be that with more participants this difference would achieve statistical significance. It is possible that situated data has both an *immediate* impact on the emergence of action and a *mediated* impact, whereas overview data has only a *mediated* impact; the overview data alters the participant's system model which is part of the contingent circumstance, whereas the situated data is used not just to update this model but also more directly alters action as as an immediately perceivable part of the environment in and of itself.

In summary, although the results did not show directly that situated data improves performance over the task as a whole, the behaviour of participants *was* altered by the situated data; the patterns of behaviour suggest situated data may encourage exploration and understanding of the problem space, and it is possible that more complex systems will show performance increases associated with improved system understanding. The experiment suggests that the degree of spatial binding alters the manner in which action emerges, and that changing the physical location of the data representation alters the way action emerges on this abstract task, but how does this translate into a real garden context? The differences that we see emerging from this one isolated element in the lab could present in a more complex manner in the real world, or even be eclipsed completely by overriding contextual factors. How do situated and overview representations differ for more complex problems, more complex data representations and more concrete tasks with real world knowledge? Are there contextual factors that interact with (or even totally overpower) the spatial locality effects? In order to address these questions, it will be beneficial to return to the garden and investigate how situated and overview representations could alter the emergence of action *in situ*. A focus on an environmental factor that changes over time in a more complex manner than fairly time-invariant characteristics such as ph (which 'affinity' in this study was based on) may generate richer interactions; an area of particular interest will be how the existing domain knowledge and customary practice interact with degree of spatial locality.

This experiment showed that the different representations *change the way people act*, rather than either being measurably 'better' than the other. Before this experiment, we were envisaging a final deployment of tangible, situated data artefacts - in effect, directly augmenting the existing markers and plant metadata that we saw in the initial interviews. However, the importance of both types of data representation was made much more salient by this experiment; rather than constraining the design space, this experiment actually opened it up in some ways, but focused attention on this situated/overview difference. One of the most important reflections from this experiment was that the *process* forces the researcher to think in a very different way than when designing, undertaking and analysing in situ studies - this helps to recontextualise all the other research activities by seeing the emergent theory from another angle. Not only is it *possible* to incorporate experiments into a RITW process, but it may in fact be *desirable*.

6.7 Conclusion

This chapter presented a study on situated and overview representation of data in dyads, using an abstract spatial learning task. It was found that the overall performance of dyads did not differ across conditions, however the trajectory of action over time was different in the situated data condition; pairs in this condition showed good scores earlier on, then oscillated between 'good' and 'less good' solutions toward the end of the task. We can say that situated data leads to action emerging in a different manner to no data or overview data, and it is possible to speculate that situated information leads to the emergence of more exploratory action. The study raised a number of questions about how these effects of spatial locality might translate into real-world contexts.

The finding that situated and overview data change behaviour in different ways helped answer the first study-specific research question, contributing to the addressing of our overall RQ2 and the development of the second primary contribution of this thesis; ‘situatedness’ may offer a useful dimension for analysing data artefacts we find in shared spaces, and also a dimension we could use as a tool for conceptualising or constraining designs. This also helps directly inform RQ1, suggesting that a mix of representations might be appropriate (rather than selecting one or the other). Perhaps more importantly, this demonstrates not only that lab experiments can play a role in a RITW process, but also supports the idea that research activities in RITW are part of an iterative process of developing emergent theory, addressing RQ3.

The next study will examine how situated and overview representations of more complex data in a community garden environment could affect the emergence of action in a real setting, and how the different representations interact with gardeners existing understanding and practice. The following chapter discusses the design of the prototypes that will be used in the next study.

7 Situated and Overview data representations in community forest gardens

7.1 Chapter Overview

The previous study showed how providing situated or overview data can impact on the strategies employed when solving a problem. The final stage of this research investigated wether the spatial type of the information provided has a similar impact in-situ (i.e. in community gardens), and if so, how. As such, this chapter presents a study on situated and overview representation of environmental data in a community forest garden. A provocative prototype was deployed in a community forest garden with a goal of eliciting responses to Situated (augmented reality) and Overview (map) representations of light level data.

7.2 Motivation

In Suchman's theory of situated action, action emerges from *contingent circumstance* - the entire current state of a situation, including both the immediately available external stimuli in an environment and the internal state of actors (Suchman, 2007), as discussed in depth in chapter 2. In our initial study, gardeners reported 'decision making' in the garden as being collaborative, 'ad-hoc' and taken in the garden (see chapter 4), which would appear to reflect this emergence of action. However, it appears the garden is not only shaped by this kind of action; various artefacts were also observed in the study reported in chapter 4, such as maps and notebooks, that suggested actions also emerge in a wider (or at least, different) scope than that of immediate 'in the moment' action. Additionally, systems designed by gardeners in the design workshop reported in chapter 5 revealed structures with both ‘situated’ components, localised in specific parts of the growing space, and ‘overview’ components, drawing information from the situated components together. This reflects the existing ecosystem of ‘situated’ components (such as markers and signs) and ‘overview’ components (such as maps and books) observed in chapter 4; this could be a simple replication or reconstruction of existing systems by the workshop participants, or could be based on a desire to support existing practice involving multiple levels of action. In either case it suggests that existing practice is broader than simply ‘ad hoc decisions’ in the garden. Presenting data using these ‘situated’ and ‘overview’ representations appears to lead to actions emerging differentially in a lab setting (chapter 6) - if this transfers to a ‘real world’ context, understanding the different roles of ‘situated’ and ‘overview’ data and how it affects the emergence of action in the garden could help to inform the design of systems for community gardens. The current study thus aims to investigate situated and overview data representations in community gardens, specifically a community forest garden selected from the study reported in chapter 4.

7.3 Research Questions

The study aimed to address three main questions:

1. How do actions currently emerge within the garden?
    - What are current practices related to ‘decision making’ in the garden?
2. What is the difference between *overview* and *situated* data representations?
    - Do the different prototypes induce different responses?
3. Are the concepts and representations used in the prototypes understandable, and useful?
    - Do community members understand the augmented visualisa-

tions?

- Can they extract information from them, and is this information useful?
- Does the prototype show them something that they were previously unaware of, or present information in a new light?

and additionally,

1. What can we learn from this process that we can use to extend the RITW framework?

7.4 Method

In order to investigate the research questions, we conducted interviews in the garden context, using a *Provocative Prototype*, designed to elicit information about existing practice and also to probe possible future use. We define a provocative prototype as being one of a class of methods that (Heyer and Brereton, 2008) describe as exploratory prototypes, research artefacts that are inspired by technology probes (Hutchinson et al., 2003), but which diverge from Hutchinson et al's 'original formulation' (Heyer and Brereton, 2008). We call this a *provocative* prototype as it is weighted towards exploring aspects of sensing and action in the garden rather than designing a solution for this specific community garden. We opted to deploy a *provocative prototype* intended as a breaching probe (Heyer and Brereton, 2010) or 'provotype' (Mogensen, 1992) with the intent of eliciting responses and actions from the community and uncover nuances around decision making and situatedness *rather than* simply investigating the context-appropriateness factors. A more detailed discussion of the motivation for provocative prototypes in general can be found in chapter 3.

The prototype system consisted of two parts - the sensors which captured data from the garden and the prototypes themselves, which participants used to access the data. There were a number of technical and situational considerations for the specific technologies used in the sensor part of the prototype[1], however the most important consideration in terms of the design of the study was *what* to measure, rather than how to measure it.

There were two main areas of decision for the design of the 'display' part of the prototype: firstly, the modality (should it be something tangible, audible, visual? Something more exotic?) and secondly the specific representation of the prototype within that modality. Similarly to the sensor component, the display aspect of the prototype had a number of technical considerations[2]; the specific implementation of technologies is beyond the scope of this thesis, and will depend upon the skills and resources available to a research team.

Light was selected as the primary focus for the prototypes following interviews and discussion with the community. In addition to being a matter of interest to the community, light levels are interesting to examine as they are visible and understood by community members, but change over time and in a more granular way than the general community knowledge based on the sites aspect (i.e., in the UK shadows are cast North more than South due to the latitude, so areas to the North of shadow casters will get less sun than areas to the South).

A *visual* approach was selected as a modality. We considered other types

[1]In particular, the lack of power and internet at the site were challenges, along with the requirement for weatherproofing. Low power packet radios (nrf24l01's) and slightly modified 3v3 Arduino pro mini's were used as nodes in a star topology, with a hub node that also had a real time clock, sd card storage and BLE radio so that data could be harvested from the system via smartphone. The solution to the power problem was to make the nodes very low power, and put the energy burden on the hub node. And attaching a big battery to it (unfortunately the hub node drew too little power to wake up the battery pack, which was designed for charging phones and tablets, necessitating the construction of a small passive circuit that pulsed a power draw through the battery pack to keep it awake).

[2]Off-the shelf AR systems available at the time did not work in the garden; instead the prototype used a mix of visual data and position and attitude data from the device, and GPS data from the experimenters phone (since the tablet in question didn't have it's own gps..). The resulting system occasionally needed to be reset by going to a known position and vantage.

of interface modalities that have been used in 'displays' for shared spaces, such as audible and tangible (see the Literature Review for a discussion of different types of public displays and installations), but ultimately selected a visual Augmented Reality approach. A 10plus10 technique was used to explore the initial design funnel, and generate variant designs (Greenberg et al., 2011) that aimed to address the challenge *"Elicit responses to possible future garden tech that shows environmental conditions, with a focus on probing the different effects of situated and overview data on community practice - without disrupting practice of community members who do not want to engage with the prototype"*. The AR concepts in this exploration offered the best opportunity to explore the situated/overview spatial mappings, and also meant that community members not participating in the study didn't have to experience the intervention. Additionally, the fact that it *was* a screen based device, but used in an interaction paradigm which participants were unfamiliar with, gave us the opportunity to be provoke responses to 'technology' in the garden space. As observed in the Literature Review, AR interfaces have very high surprise and novelty factors (as in Javornik et al. (2016)) but may get in the way of performing tasks. This combination of surprise/novelty and 'unreadiness-to-hand' can be a *benefit* in a provocative prototype, since working with 'unready-to-hand' tools causes action to become explicitly manifest, allowing us to probe into it, rather than the interaction becoming 'invisible' (Suchman, 2007).

7.4.1 Sensors

Four light sensors (Figure 7.3) were deployed in the garden by a community volunteer and the researcher in order to capture areas which were of community interest (Figure 7.1). Four sensors were selected in order to provide enough points for interesting comparisons between sensor locations, without overloading participants with data. Two of the sensors were placed at the north and south of a Hügelkultur (Figure 7.2), a raised bed variant designed to model natural forest edge decomposition processes. The remaining two sensors were placed in two adjoining beds to the north of the Hügelkultur, at the foot of the main trees in each bed. The sensors were placed in these locations because it allowed comparison both within pairs of sensors in similar locations (the Hügelkultur pair and the forest bed pair) and between the different locations in the garden (the Hügelkultur to the South and the forest beds to the North).

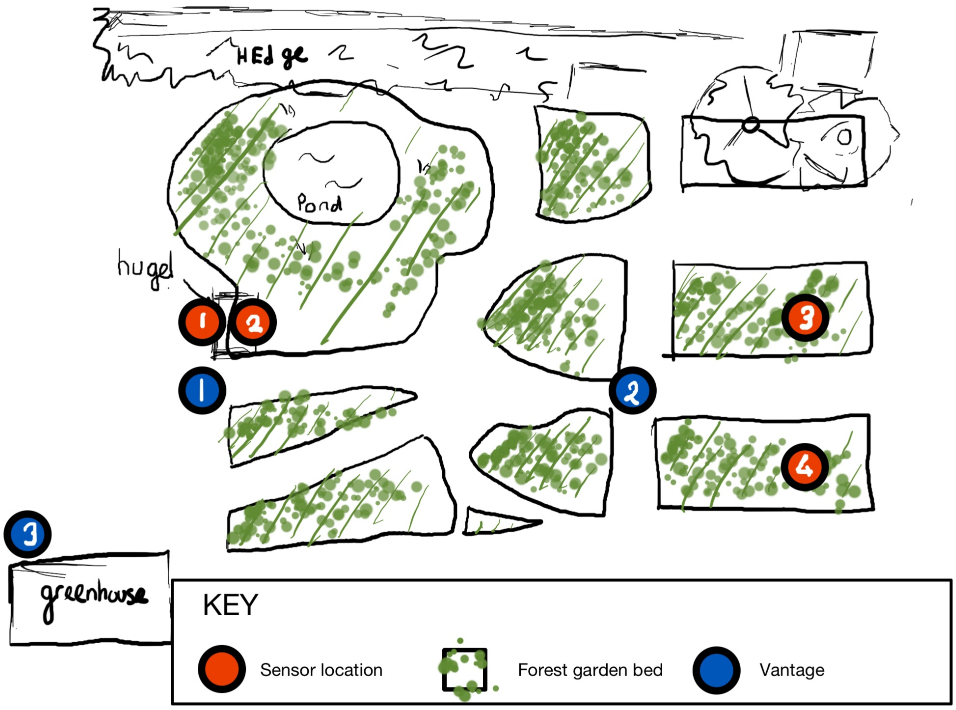

Figure 7.1: Sensor placements and prototype vantages. **NB** This map shares the same orientation as the iPad prototype, thus North is to the right

The sensors captured light measurements every 15 minutes for 3 months prior to the interviews, and this dataset was used by the prototypes.

7.4.2 Prototypes

Situated and Overview prototypes were created that both ran on the same iPad. The Situated prototype used an Augmented Reality (AR) video

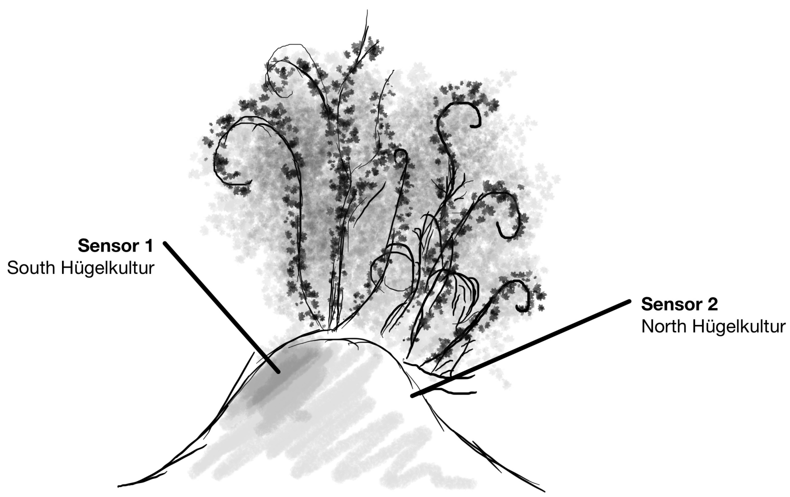

Figure 7.2: Hügelkultur sensor placement

Figure 7.3: A light sensor in the garden

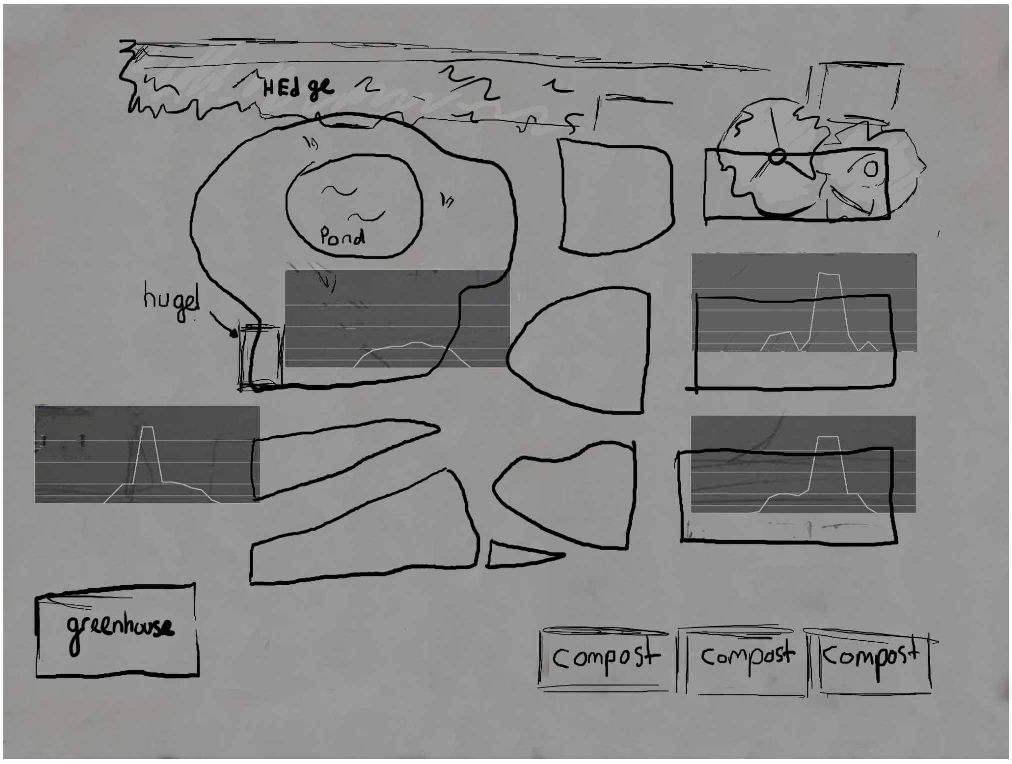

Figure 7.4: Overview prototype

Figure 7.5: Situated prototype

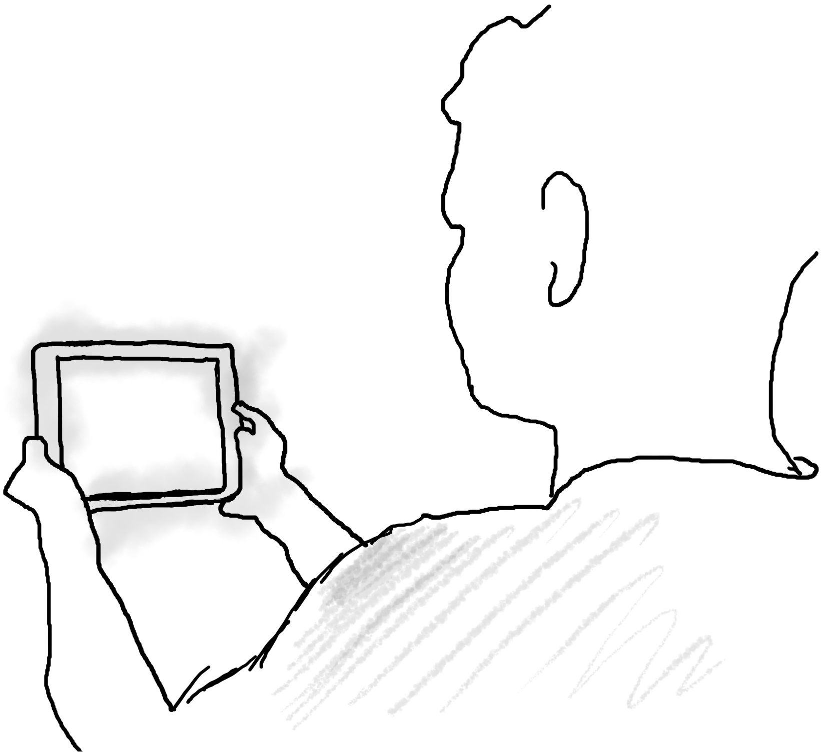

Figure 7.6: A participant 'looking through' the situated prototype

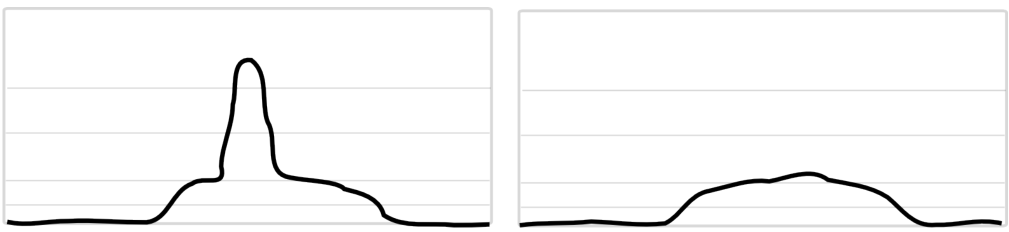

Figure 7.7: Sensor data line graphs. Left, the southmost Hügelkultur sensor (sensor 1); Right, the northmost Hügelkultur sensor (sensor 2). Note the spike in light levels around midday for the Southmost sensor.

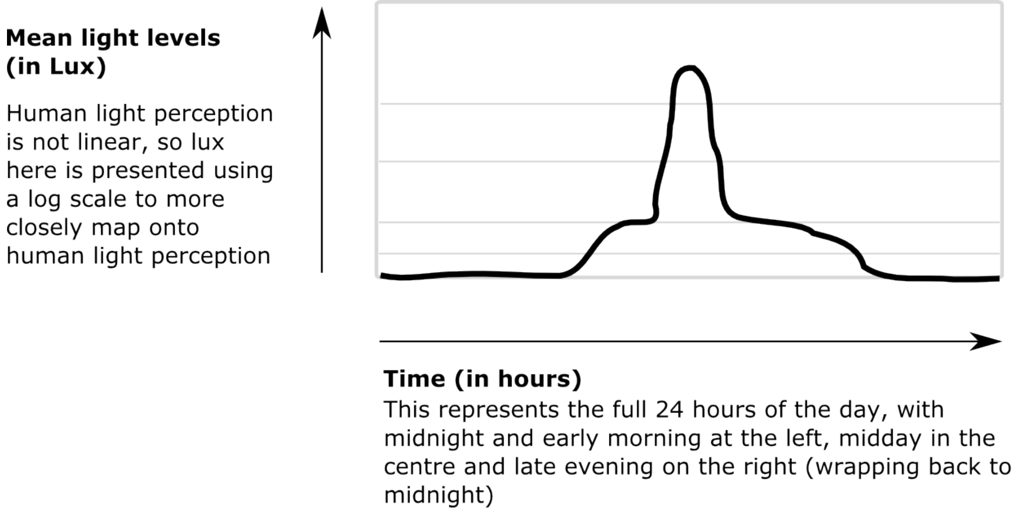

Figure 7.8: Line graph of mean light levels per hour. This representation is used by both prototypes

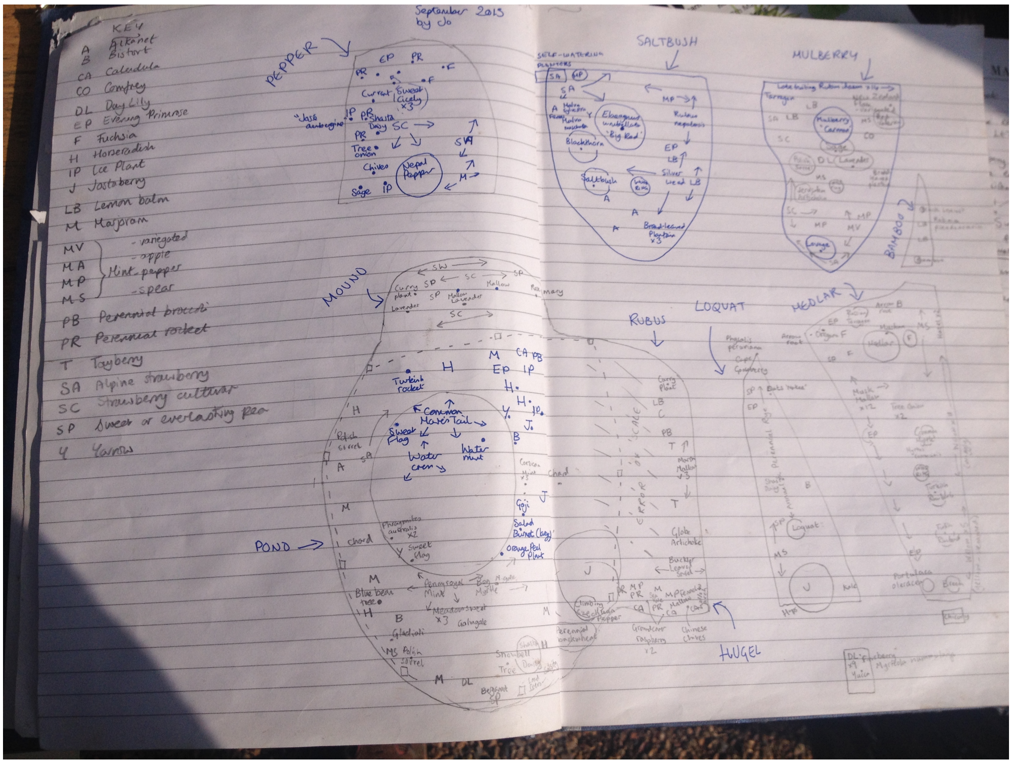

Figure 7.9: A sketched map from the greenhouse. This is from the map book mentioned in chapter 4. The overview prototype is based on this map

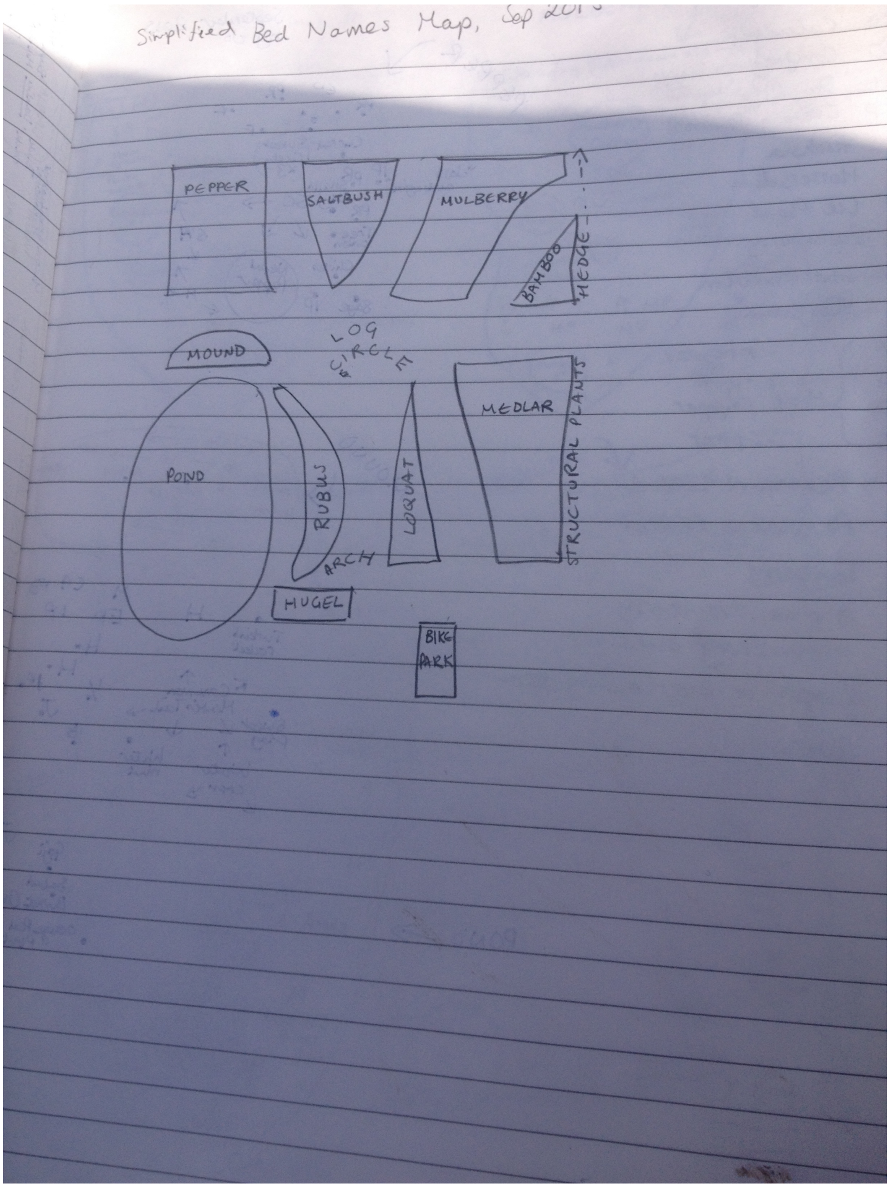

Figure 7.10: Another map from the greenhouse, showing the same part of the garden but in a much simpler form

overlay approach to show data, rendering sensor data on video from the device camera in such a way that it aligned with the real world location of the sensors (see Figure 7.5) and the Overview prototype used a map view to show the same sensor data (see Figure 7.4). In essence, within their representation of the world both prototypes bind the data to its location; the Situated prototype does this in a three dimensional, first person reference frame whereas the Overview prototype uses a two dimensional frame. As a result, the Situated prototype only displays data which is in its field of view, whereas the Overview prototype always shows all the data. This difference in degree of physical abstraction is the main difference between the prototypes; the Situated prototype provides data directly in the environment and the Overview prototype provides the data on an abstraction of that environment.

Both prototypes represented the sensor data using the same visualisation. The data in both prototypes was presented using a simple line graph (shown in Figure 7.8), with mean light levels shown for each of the 24 hours in a day. This simple representation was selected to focus the study on the differences between situated and overview representations rather than the specifics of the visualisation itself.

There are interesting questions of time and space in how to present the light level data, as the cyclical nature (over days and the course of the year) is important, as is the laminar structure of lighting levels in forest gardens (Jauralde Hart, 1991), however we decided not to investigate these cyclical and 3-dimensionally layered aspects in order to retain the focus on the *situated* versus *overview* aspects.

There are a number of approaches to representing time data with various benefits (see Figure 7.11 for some examples) - for instance, radial (and particularly spiral) representations can help identify cyclical patterns, but they are harder to use than calendar representations, and less preferred than timeline style visualisations although performance is similar (Koeman and Power, 2012). In the end, it was decided to select a *simple*, *familiar* data representation - a line graph of mean light levels by hour. Although this representation elides the differences over the larger seasonal cycle, it does maintain the differences over the course of a day. This less deep visualisation is more immediately approachable to participants but not so processed that it is ‘pre-analysed’. We wanted to strike the right balance of depth, with a visualisation that was approachable and not overwhelming, but that allowed some scope for analysis and interpretation.

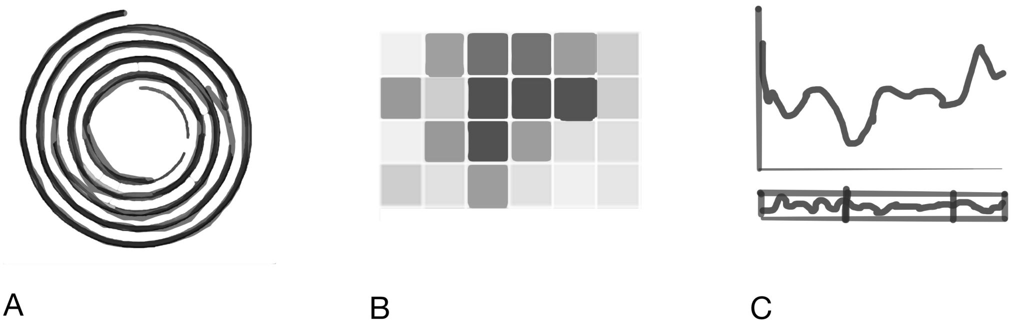

Figure 7.11: Temporal visualisations. A) Spiral visualisation based on Weber, Alexa, and W. Muller (2001) - useful for spotting trends in cyclical data. B) Tile Maps based on Mintz, Fitz-Simons, and Wayland (1997). These are intended to show data with seasonal patterns at multiple levels of granularity .C) A more traditional timeline - users experience this as familiar and easy to use, although their measured performance using this kind of visualisation is no better than ‘more complicated’ spirals (Koeman and Power, 2012)

The axes were left unlabelled, and additional ‘helper’ elements such as current time of day indicator and current levels indicator were omitted. The goal of this was to maintain provocation and ambiguity, rather than testing a specific set of interface elements.

The Situated prototype is based on the ‘situated’ artefacts identified in chapter 4, specifically the markers, and the Overview prototype is based on the ‘overview’ artefacts identified in chapter 4, specifically the maps. In the latter case, the map used in the overview prototype is derived from the existing sketch maps identified in this garden (including Figure 7.9 and Figure 7.10), and attempts to retain the ‘sketched’ looks as much as possible.

As previously discussed, technical implementation is outside of the scope of this thesis, however there is one aspect of the technical setup that will be discussed here as it has a bearing on the study design: The AR prototype was initially intended to use visual methods combined with the device's inertial sensors to localise itself. Unfortunately, off-the-shelf systems (such as Vuforia) were found to be insufficiently robust in the garden[3]. It is possible that the self-similarity of the environment, the large scale and the continuous changes in the environment over time (such as light levels, and growth of plants) were problematic for these systems. As such, the prototype used in the garden relied on a combination of visual input and the device's inertial sensors to determine the device pose, and location data provided by a second device (the iPad used did not have telephony or GPS). The drift from the inertial sensors and the variable error in the subsidiary device's positioning meant the iPad's location was not always tracked accurately. To address this somewhat, the prototype had 3 predefined vantages (see Figure 7.1) which the researcher could select, allowing moving to a vantage and manually updating the app's position. The researcher always began in vantage 1, to achieve a stable initial state. This did not appear to affect the credibility of the prototype for the participants, as the local pose tracking at each vantage was sufficiently robust over the course of each session. Rather we report this because it prevented a fully free exploration of the garden with the prototype, presenting a constraint on the study. For instance, if a participant had wanted to walk as far as possible away from the sensors and turn to look at them (about $\sim$100m before reaching the edge of the space), the whole set of graph representations would have likely been offset from their actual positions (Although no participants attempted this).

[3]after the conclusion of the study, Apple released a beta version of their AR API ARKit in their developer betas on iOS. Some limited testing indicates this technology is promising for more robust localisation, potentially allowing for longer term deployments of prototypes into the wild in the future.

7.4.3 Participants

Six participants were recruited from one of the community gardens investigated during the earlier case studies (chapter 4), through a combination of opportunity sampling and snowball sampling; volunteers were approached during sessions at the garden and were asked to refer additional participants. This particular community is engaged in *forest gardening*. Forest gardens attempt to emulate a forest edge ecosystem, and are composed of trees of various ages and sizes and smaller plants. There is a focus on the utility of plants, (both in terms of edibility and other uses such as medicinal use), and on sustainability; forest gardens are intended not to use inputs such as fertiliser or irrigation. Unlike a monoculture environment where the aim is to optimise conditions for specific plants, the forest garden aims to create complete ecosystems; the selection of appropriate plants and design of the ecosystem is a complex problem where additional data inputs could be especially valuable, making this a particularly interesting type of community to investigate.

All of the participants (five female and one male) were experienced volunteer gardeners, with at least 2 years of experience of both gardening and volunteering in different types of gardens. Five of the participants were 'site leaders', volunteers who regularly attend and lead volunteering sessions', and there was a moderate mix of attitudes to technology and comfort with technology amongst the participants. See Table 7.1 for more detail.

We focused on these experienced and involved volunteers as their understanding of the space and the community's practices is greater than casual volunteers, and it also appeared from the case studies in chapter 4 that these more involved volunteers may have greater input into actions in the garden.

Table 7.1: Table of participants

Participant	Gender	Site Leader	Trustee	Attitude to 'technology'
p0	female	yes	yes	Positive: but ambivalent about technology in the garden.
p1	male	yes	yes	Slightly Negative
p2	female	yes	no	Positive: This participant blogs professionally, and is excited about the idea of using technology in the garden
p3	female	no	yes	Somewhat Negative: This participant is not a regular user of computers tablets or smartphones.
p4	female	yes	yes	Neutral
p5	female	yes	yes	Neutral: this participant is comfortable with smartphones and tablets. They are wary of technology in the garden, but feel there is potential for data and sensor tech in forest gardening

7.4.4 Setting

The community of interest runs a community forest garden, set within a public park in North London. A forest garden attempts to model a forest edge ecosystem, focusing on sustainability, biodiversity and utility. The group's goals are to create and maintain a forest garden, to promote temperate forest gardening through teaching and example and also to propagate plants that can be used by other organisations. Other community organisations take plants from the group in exchange for donations.

At the beginning of this study, volunteers worked at the forest garden twice a week on Mondays and Fridays, however this has recently been reduced to Fridays, due to two senior community members having less time time to commit to the site. The garden is transitioning to formalising its system of 'Site Leaders', volunteers who are experienced gardeners and who run volunteering sessions and coordinate volunteers who attend the sessions. The number of volunteers who attend one of these volunteering sessions is highly variable; some days no volunteers will arrive, other days there can be more than ten, and there are often events leading to a brief influx of volunteers such as corporate social responsibility days. The typical activities on one of these volunteering days include weeding and propagating plants.

The site is roughly 25m by 75m, of which around 25m by 20m is actively managed by the forest gardening group. The site is a rectangle broadly aligned North-South, with the long 75m edge of the rectangle being North-South and the short 25m edge being aligned East-West. A square 'edible showcase' bed is located near the entrance to the site to the South, and a number of 'forest garden' beds are planted to the North, shading into a number of mature trees. This study focuses on the forest garden section of the site to the North.

7.4.5 Procedure

Participants were interviewed in the garden during volunteer sessions. The interview was semi-structured, with each of the sections having research questions that the researcher aimed to answer by probing initially as openly as possible and progressing through more direct probes. The researcher and participants were engaged in gardening tasks during the initial portion of the interviews, moving to specific points in the garden to examine the prototypes, as the majority of the interviewees were performing their role as site leaders when the interviews were initiated. This had the benefit of the participants being in the garden context (both physically and in terms of tasks), however interviews were frequently interrupted by the demands of the participants' role; volunteers and visitors would approach with requests of the interviewee, and occasionally volunteers interested in what was happening would approach to talk to the researcher. There were also environmental interruptions such as low flying aeroplanes, surges of loud traffic, and sudden rainstorms. To recover from these interruptions, the researcher would repeat interrupted questions or in-progress answers.

Each 60 minute[4] interview was preceded by a participant briefing and consent form signing. Participants were informed that the study was about light level sensors that had been placed in the garden, that they would be asked some questions about their background as gardeners and about the group and their role in it, and that they would use some prototypes and discuss these, and that the sessions would be recorded for later analysis. Participants were also informed that they could withdraw their data at any time, and that they would receive a £15 amazon voucher in exchange for their participation. Participants then read and signed the consent form, and the experimenter began the recording.

Following this briefing, the session began with a 10 minute background interview. The goals of this background interview were to elicit current practice with a particular focus on actions relating to planting, gather some background information on the participants (such as their experience as a gardener and at this site in specific) and additionally to set participants at their ease by ensuring initial questions were ones they could readily answer (being questions about themselves and their activities in the garden), rather than immediately presenting unfamiliar technology.

After this initial background section, the researcher proceeded to the Situated Prototype (Augmented Reality) section of the of the study, commencing with a short briefing then an initial exploration by the participant before moving on to directed activities using the prototype. The objective of this activity was to understand users' reactions to the prototype, examine possible future use and also to elicit information about current practice.

The briefing consisted of the researcher showing the participant one of the emplaced sensors (sensor Number 1, the Southernmost of the Hügelkultur

[4]Nominally. The timings varied in practice from 40 minutes up to 90 minutes due in part to different levels of external interruption in the garden. Additionally, some participants were eager to continue discussion at the end of the interviews.

sensors - see Figure 7.1 and Figure 7.2), and explaining that there are a number of these sensors in the garden and that they measure light levels and that this section of the interview involves them using prototypes that show the information from these sensors. This briefing aimed to give some context to the prototypes (as the participants are not casual volunteers and can be expected to have a certain level of awareness of infrastructure and tools in the garden), but retain sufficient ambiguity to probe conceptual understanding. The Southernmost sensor (sensor 1) was selected as an exemplar as it allows an initial focus on the Hügelkultur where the difference between the two Hügelkultur sensors was more pronounced than the difference between two sensors further to the North. Additionally, the Hügelkultur sensors were easier to see, access and replace than the Northen sensors.[5]

Following the briefing, the researcher and the participant were standing to the Southeast of the Hügelkultur, looking towards the Hügelkultur. (vantage point 1 - see Figure 7.1) At this point, the researcher initialised the Situated prototype on an iPad, and handed the iPad to the participant such that it was in a landscape layout and perpendicular to the ground so that the participant was 'looking through' it at the Hügelkultur (see Figure 7.6) such that two of the sensor graphs were visible, commencing the initial exploration of the Situated prototype. During this subsection of the interview, the researcher gave minimal prompting to the participants; initially no prompt was given, and if participants did not begin talking about the prototype unprompted, the researcher used open prompts to induce discussion, such as *"tell me about this [while indicating iPad]"* or *"what is this telling you? [while indicating iPad]"*.

After the initial exploration, the interviewer began the activity driven tasks; in this part of the session, the interviewer would give the participant the following instructions (optionally asking the first question again with a different plant and with the opposite light/shade preference):

[5] One of which has yet to be recovered as it can't be located in the undergrowth, despite being bright pink.

1. Imagine you have some [plant that prefers sun/shade] that you want to plant. Show me which of these areas would you plant it in.
2. Imagine you want to plant something in this area [indicate an area]; Tell me what would you plant there.

The specific plants were based on those that participants had previously mentioned (if relevant), or a plant present in the garden with the appropriate characteristics (i.e., Solomon's Seal for shade preference)

Some participants moved around the garden in this part of the interview; when the prototype's localisation error was high enough to be confusing (see subsection 7.4.2), the researcher guided the participant to nearby preset vantages with a known location. These vantages were chosen to allow probing of particular aspects of the prototype; for instance, position 2 allowed the participant to see the Northern sensors and rotate around to see the Southern sensors, and position 3 (see Figure 7.1 for a map) allowed the participant to see all four sensors at once.

Following the Situated prototype section, the researcher would introduce the participant to the Overview prototype (map). The Overview prototype was run using the same iPad as the Situated prototype; the experimenter took the device, tilted it into an angle between 65 degrees and horizontal to the ground (which launched the Overview prototype), and handed the device back to the participant. This part of the interview followed the same structure as the previous Situated prototype section, excluding the briefing; an initial exploration followed by the same two activities and cumulating in a discussion.

The session was concluded with a 10 minute discussion and debriefing activity, during which the researcher asked for the participant's overall thoughts and opinions about the prototypes and gave the opportunity for that participant to discuss anything they had not already mentioned, examined any interesting areas not yet covered, and thanked the participant. Additionally, at this stage the researcher also probed interface representation preference.

7.5 Results

The audio recordings from each participant were transcribed and coded. The findings are grouped here broadly by the chronological progression of the interviews, into *current practice*, *situated prototype* and *overview prototype*.

7.5.1 Current practice

Participants reported during the background segment of the study that planting decisions were taken collaboratively, in the garden and on an ad-hoc basis, which accords with the findings from the case studies reported in chapter 4. For instance, p0 described the following as being a common case: *"umm … I think [other volunteer] said 'oh we could do with some ground cover' and I was like 'oh we've got some strawberries…"'*. The gardeners see their day-to-day activities as being primarily about maintaining the garden, and in contrast to these day-to day maintenance activities, participants saw making large changes to the garden as being a *design* activity, different from the 'ad hoc' decision making reported in the case studies. For example, p1 said: *"with something like a forest garden, most of the effort is… is in the establishing of it, and the setting it up … and then after that, you kind of … letting the natural … processes kick in and you know, the … so it needs less management anyway"*. These design activities seem to be linked to the overview representation for gardeners - for instance, at the end of the session, p1 mentioned of the map overview: *"I guess you would probably use this when you are initially … designing an area, planting up …"* - p1

There appear to be two different types of action that emerge in the garden, the everyday action that emerges in the garden at a bed level whilst undertaking 'maintenance' tasks, and rarer 'design' action that takes place both in the garden (in the greenhouse), and outside of the garden.

7.5.2 Situated prototype

The general use of the line graphs was understood by all participants, with all of the participants identifying that the x axis represented 24 hours and the y axis represented light levels (*"uh thats probably the peak uh 24 hours so thats the night and thats uh midday and this is the one behind so it takes less sun because its all covered by ... the plants."* -p2), however two participants initially struggled to grasp the concept of the Situated prototype in the initial exploration phase. Despite understanding that the data was related to the world they were seeing, these participants appeared to find the idea that the data was spatially bound to the sensors challenging; both p0 and p4 asked why two graphs were visible on the Hügelkultur - when pressed, both suggested the second might be moisture, indicating that it wasn't clear to these participants that there was one graph for each sensor. Later, even after explanation and observing the sensors from multiple vantages, p0 asked at the very end of the session 'why could I see the plants through the screen? Was it ... to make me feel more comfortable?', suggesting that these issues with understanding may extend beyond initial use.

Two participants started discussing how they could use the information for making decisions even before being prompted by the activities: *"like if I uh, if I'm planting, I dunno, sunflowers that needs full sunlight or a hydrangea that needs shade I would know ... "* - p2, and all participants made reasonable planting decisions during the activities, however participants appeared to be combining information from the graphs in the situated prototype with their existing knowledge of the garden and light conditions rather than receiving completely new information; for example p1 said *"... i'll know from the direction... it might help ... on a more micro-scale... cos obviously the hügelbed is gonna cause some amount of shade that the other side and maybe ... uhh maybe people wouldn't have thought of that".* p3 showed a clear example of this - she initially said *"thats interesting"* on looking at the sensors on either side of the Hügelkultur, then proceeded to work through why *"theres a spike on the left..."* (why the Southernmost side shows a large spike at midday but the Northernmost doesn't). After a few minutes of talking through why this should be, p3 then exclaimed 'but of course its all obvious', and later reiterated that the Situated view wasn't useful because it was 'obvious'. This initial interest, insight generation then internalisation was evident in a number of participants.

4 participants indicated that something other than light would be *"more useful"* (suggestions included moisture, frost, wind, and photosynthesis), or that the tool would be useful 'in a more complex garden'-p0 or 'in my garden at home' -p2, despite appearing to gain insight from the data in the situated view.

7.5.3 Overview prototype

Participants struggled to localise the sensor positions of sensors on the Overview representation. For example, p1 found it difficult to understand where the graphs on the map were in the real garden, and participants requested additional interface elements to pinpoint the maps *"you could have like.. little dots on the paper map to show where they [the sensors] are…"* - p0. Its possible that this is a prototype issue and not inherent to map representations. The majority of participants found it more difficult to localise the sensors in the Overview prototype than the Situated prototype, even those who had initially struggled with the AR concept. However, despite this, all participants stated a preference for the map view, either unprompted or when asked in the debrief section of the interview.

3 participants mentioned that the Overview prototype would be useful in designing gardens, and 3 participants discussed the desirability of having parts of the iPad map view combined with parts of the physical maps. p0 specifically wanted 'those graphs on this map' and p2 wanted to be able to 'click on the map and get .. all the information'.

7.6 Analysis and Discussion

There are two different strands of action demonstrated in the existing practice; one which emerges in the day to day ‘maintenance’ context and one which emerges in the rarer ‘design’ context. Despite participants conceptualisation of the day-to-day context as ‘maintenance’, much of the action that emerges in this context leads to changes to the garden, not just a maintenance of the status quo: in the strawberries example from p0, there are two alterations (add ground cover, add strawberries), and given the apparent rarity of the design context, it is possible that much of the shaping of the garden occurs through emergent ‘maintenance’ action. It appears that situated data can lead to the generation of new insights in the ‘maintenance’ context, however most participants didn’t recognise this; participants indicated that it was ‘obvious’ (p3) or ‘reconfirming’ (p2), or state that the prototype would be useful - but for a different metric or in a different environment - immediately after demonstrating interest and rationale building around the data. Possibly the new knowledge becomes internalised through the process of ‘thinking it through’ by the combination of existing knowledge about the environment (such as aspect) with data from the graphs. For the participants who seemed to be understanding something new, the data appeared to be a trigger to applying domain knowledge; specifically the surprise that sensor 1 (on the south of the Hügelkultur) should have such a drastic spike which sensor 2 did not share. It is even possible that the data itself is not the most important factor, but the reframing - simply presenting ambiguous data or an information-free reframing device could lead to similar behaviour.

The overview prototype was more associated with the ‘design’ context by participants: in the initial ‘background’ part of the study, participants emphasised the importance of their role as maintainers, but the overview prototype seemed to induce them to discuss design and planting (reinforcing the findings from the previous study that there is a difference between situated and overview representations, thus addressing RQ2 and supporting the second primary contribution). There was an overwhelming preference for the overview prototype, and the findings suggest three possible causes for this: First, it could be argued that this preference is due to internalisation of the insight generation triggered by the situated prototypes leading participants to perceive the situated prototype as less useful. Second, it is possible that the nature of the data is seen as being useful for planning and design but not 'day-to-day' garden maintenance, thus its not the representation thats preferred *per se* but rather that the framing as a design tool is more appropriate. Finally, it is possible that in contrast to the arguments of Bidwell and Browning (2010) and (Robinson, Marsden, and M. Jones, 2014) the more abstract Overview interface is counterintuitively perceived as being less disruptive to presence in the garden; since the 'design' action doesn't arise from being wholly 'present' in the garden, augmenting it with technological tools is seen more positively rather than something a 'metal and plastic thing between you and the garden' (p1) thats causing a 'disjoint … that makes me feel less present' (p0)

The 'local reframing' (via data or otherwise) induced by Situated data could lead to more optimal action emerging in the garden in a non-intrusive manner, as the resulting action seems so natural that participants do not realise they have altered their understanding. However, this lack of realisation is also a potential barrier for uptake and use of such a system - if people do not realise it is working, why should they put it in the garden in the first place and update it? Taken together, the findings from this study suggest that providing community champions (such as the site leaders in this study) with tools that use overview representations or augment existing ones to help them to *create* situated representations may lead to more effective action (such as better planting decisions) emerging in the space than presenting the data directly in the space.

To return to Lucy Suchman's canoe analogy, the canoeist examines the rapids in overview first, orienting themselves (physically and mentally) to take best advantage of their embodied skills in the situated environment of the rapids. Providing community champions with an overview can help them to orient not just themselves but other volunteers (through the authoring of situated representations), to better respond to the 'rapids' of day to day action in the garden. For instance, an augmented shade map of the garden could be used to plan out where new forest garden beds should be placed, or to identify areas where certain types of plants should be favoured or avoided; the champions could then place situated markings in these areas using novel technology or existing marking techniques (such as the stakes and signs), which would cause volunteers to make different decisions in-the moment.

It is even possible to speculate that supporting this kind of 'meta-action' that community champions undertake to reshape the shared space (and ultimately thus the actions that emerge in it) is a potential fruitful avenue for considering the design of data tools for shared spaces more generally, although it is not clear how this would generalise to spaces that lack the 'editability' of the garden. This is of particular relevance to RQ1, since it suggests that designing different representations for different community members or different types of action could support this kind of shaping of the space; the different aspects of a system may fill different niches in a very asymmetric manner, as opposed to fitting together into a clearly defined system.

These findings also have implications for RQ2; the local reframing from the situated representation, vs the more 'designerly' behaviour induced by the overview representation supports the findings from the experiment study that these representations lead to different kinds of action emerging. The integration of local data vs planning echoes the differences in behaviour observed in the experiment, demonstrating that the different degrees of spatial binding shaping action differently may be applicable to a wider range of tasks and contexts outside of the lab.

7.6.1 What can we learn from this process that we can use to extend the RITW framework?

An augmented reality approach with a limited visual representation was selected for this prototype. This is not to say that we believe this modality and representation are ideal for a *real deployed system* - however, the goals of probing and discovering are not necessarily the same as those of the community. There is a tension here between the researcher's goals and the community goals. In an ideal world, our projects would be initiated by communities and goals would be aligned (Balestrini, Bird, et al., 2014), however this is not always the case in the real world. There is a dialectic here between *fit* and *finding*; or what is *best for the current situation* and what is *most interesting*. As a practitioner it feels uncomfortable to 'do the wrong thing' for the community, and a lack of sensitivity to the community could lead to a lack of engagement with the research - however, the provocative aspects that go beyond (or even against) current practice elicit interesting and novel findings, that potentially could be used to feed into novel facets of a more 'conventional' system, or alternatively a totally new kind of system.

We can use the experience of the design process to concretise and operationalise these decision stages to make it easier to make these design decisions as part of a practical RITW process, and also to make it easier to discuss them in a concise format (such as in a paper), but additionally the design process was in itself a part of the construction of the emerging wild theory; as with the lab experiment in the previous chapter, the very process of designing the prototypes provides a structured way to think about the domain and examine our biases and assumptions.

Reflecting on the process taken to design the prototype, we identified the following core steps and questions that we went through:

Core Question: What do we want the prototype to achieve? Once we had identified the design challenge that the prototype should address, we engaged in a process of design in which there were broadly three levels of decision, increasing in specificity for each level, which we identify as:

1. Which Technology, **2. Which Modality**, and, **3. What Representation**

This narrowing set of decisions could be useful in guiding design in a RITW process - this is discussed further in the Discussion chapter. Another important factor in decision was also the *provocativeness* of the prototype: This was a difficult dimension to conceptualise and balance, but on reflection is vital to eliciting data on *future* behaviour and additional aspects of current behaviour which observation alone did not uncover. In the next chapter we discuss some potential methods for approaching this question of *provocativeness*.

7.7 Conclusion

This chapter presented a study on Situated and Overview representation of environmental data in a community forest garden, using provocative prototypes. It was found that the Situated and Overview representations of the same data led to different responses. Situated data appeared to lead participants to gain insight by considering smaller spaces in a more granular way, but this is not recognised as new knowledge as it seemed 'obvious' in hindsight. In contrast, Overview data appeared to lead the participants to consider the design and structure of the garden. A system that supports community champions in creating situated representations, using an overview representation, may be an effective way of supporting actions in shared spaces.

8 Discussion

The work presented in this thesis investigates the tension of benefit versus non-use of sensors in community gardens, using a mix of methods within the recently presented Rogers and Marshall (2017) RITW framework. In this chapter, we discuss the two primary contributions of the thesis:

1. **Domain Specific Findings**

   Key themes related to action in the garden and implications for the design of interactive technologies for these contexts

2. **Empirical Findings**

   Observations on situated and overview data representations in shared spaces, and the effects of this on the emergence of different types of action

and the secondary contribution of the thesis:

A. Methodological Findings

   Reflections on the use of the RITW framework, and proposed adaptations based on use and adoption of the framework.

The scope of this thesis was focused on *sensing and data in community gardens* , which gave rise to our overall research question:

How can we design sensor and data systems for shared spaces that address the tension of non-use versus potential benefit in community gardens, and encourage use and appropriation by community gardeners?

In order to answer this overall research question, this thesis applied the RITW framework to the problem domain of supporting community gardens with data tools. Through a series of four studies we arrived at domain specific findings about designing for community gardens, empirical observations about situated and overview data representations in shared spaces, and additionally reflected on the adoption of the RITW framework as a normative rather than descriptive framework.

The initial contextual study laid the groundwork for the domain specific findings, in particular the importance of *Presence and physicality* which would become a recurring theme. Additionally, we observed different types of artefacts in the garden space which sparked initial thoughts about the nature of situated/overview data in the garden. Reflecting on the study, we saw that RITW is an *iterative* process, and the researcher needs an entry point into the process. We also began to develop the idea that RITW is a process of generating an *emerging theory*.

The findings from the workshop altered our understanding of the relationship to data in the garden, by adding nuance to the nature of the situated/ overview data, and to our understanding of gardeners' attitudes to automation and technology. From the workshop study, we further developed the idea that the iterative RITW process is about developing emergent theory in order to constrain the design space for the RITW deployment.

The experiment study showed behaviour *differences* with situated and overview data - based on findings from the first and second studies, we had thought that observing which of the types led to a performance *increase* might help to constrain the space for the deployment, but the finding that the *situatedness* of the data actually leads to *qualitatively different types of behaviour* encouraged a reconsideration of earlier findings in terms of *situated action* and how the different spatial binding of data holding artefacts in the garden could lead to the emergence of different types of data. As such, not only did the experiment provide a straightforward design constraint as hoped, but it actually contributed to the researcher's emerging conception of the research. Additionally, reflecting on the experiment helped us understand that just the process of *framing and designing the research* led to development of our understanding of the emerging theory, not just the findings.

The provocative prototype study not only confirmed that situated and overview representations of data support different *types* of action in the wild, but also revealed different types of behaviours that participants *currently* engaged in, that we did not observe in the earlier contextual studies.

The impact on the development of the emergent theory through praxis seen in the experiment study was also observed in the provocative prototype study - engaging in the design process of the prototype and the study lead to conclusions around the importance of provocativeness and situatedness in the design of RITW in general and to shared spaces in particular.

8.1 Domain Specific Findings

The first primary contribution of this thesis is a set of findings specific to the domain of community gardening. This addresses our first research question:

8.1.1 RQ1: How can we design technologies to support Community Gardens?

The first two themes about **Being in the garden** and **Automation** are similar to findings from previous research, however the importance of **teaching and learning**, **materials reuse** and **different types of action** are more novel.

Being there in the garden is core to the community gardening experience.

This was a recurring theme, observed throughout the different studies. In many ways, this underlies many of the other findings. Gardeners do not just want to be *physically* present in the garden, but also *experientially*. Participants frequently discussed variations on getting “hands in the dirt” or “getting close to the soil”, and many of their concerns about technology were related to the worry that systems would get “in the way” of just being in the garden. This dovetails with both Odom (2010) and Goodman and Rosner (2011) who also observed this desire to “get close to the soil” amongst gardeners, and this is even present to some degree in commercial concerns, such as the participants’ need to visit, see and touch the crop in Burrell, Brooke, and Beckwith (2004). This is more than just an urge to get back to nature, and physically getting “close to the soil” - this represents actively engaging in the space and with the community, and developing and transferring skills within it (see *Teaching and learning is important*).

This is not to say that interaction with the garden *stops* at the garden fence; in the workshop participants discussed many external garden-related activities, including remote viewing of gardens, remote access to data, existing practice involving reading up on specific and general topics discussing the garden with others. However, being in the garden is important, and there is a need to *augment* this, not interfere with it.

Design principle: Support physical presence in the garden. Don’t get in between gardeners and the garden.

***Automation* can damage the gardening experience**

We saw throughout the contextual, workshop and prototype studies that community gardeners aren’t inherently opposed to novel technology. However, they *are* opposed to having agency taken away from them; although gardeners initially expressed the desire to automate some aspects of gardening, this quickly became problematic.

For example, in the Sluganator design- even though the group designed this robot to automate a task they reported as boring (namely, pest control), the default behaviour they designed was to *identify* and locate pests, so gardeners could take action, not the Sluganator. Watering was a recurring task where the same behaviour was observed - participants would initially identify it as a boring task and discuss the potential for automation, before changing their minds - such as Holly and Rachel’s discussion at the Glasshouses site.

Additionally, there are benefits of actually doing tasks, both practical and experiential. This is related to both the importance of *being in the garden* and *teaching and learning* within the garden, both of which automation could potentially disrupt. This elucidates some of the motivation behind the desire to avoid automation seen in Goodman and Rosner (2011), where gardeners did not want to be ‘cut out’ of the process.

In both practical automation and knowledge support, gardeners want to be *helped* but not *told what to do*. This again echoes Odom (2010) and Goodman and Rosner (2011) who observed rejection of automation. However based on our findings, it is not true that automation *per se* is bad: the workshop and contextual study examples given above show a certain ambivalence or nuance around automation that is reflective of the larger tension around benefits of technology and disruption of experience. The important thing here is not so much *automation is inherently bad* as *don’t take agency away from the gardeners*.

Design principle: Help gardeners do things, don’t do things for them. Help gardeners learn things, don’t tell them what to do.

Teaching and learning is important

There was a spectrum of attitudes across the different groups and individuals in the studies in this thesis, from explicit teaching and learning goals (both within the community and in visibility and outreach to the wider world), to focus only on personal learning. However, a constant was ‘learning by doing’, and almost as common was ‘raising awareness’ by example. This ties into importance of *being in the garden*, which enables what Lave calls legitimate peripheral participation (Lave, 1991). Projects in many of the communities are not just for the community members, but also for visitors. This includes both aspects of the physical space (such as the demonstration planters in the Glasshouses and the showcase beds in the Forest Garden), but also broader public engagement activities (such as the events at the City Farm). Projects explicitly about this public engagement/wider teaching (such as in (Heitlinger, Bryan-Kinns, and Jefferies, 2013)) can be of value, but its important not to neglect to ensure daily-use systems providing opportunity for teaching and 'learning by doing'.

Design principle: Support learning by doing and legitimate peripheral participation.

Materials Reuse is common, and desirable

Materials re-use was observed across communities, and even (largely serendipitously) in the design workshop. This is more than just an aesthetic consideration; there is a combination of explicit sustainability goals and a 'make do and mend' attitude. Adaption of available materials and tools to needs of the garden was extremely common, for practical and ideological reasons. There was also a strong culture of *bricolage* across the communities, with a practice of toolmaking and adaption; on one level, simply fitting into the aesthetic of the garden could help to improve adoption of novel technologies; but at a deeper level, provision of flexible tools that can be adapted and transferred as skills and praxis is likely to be more successful that a single-use tool.

Design principle: Use found materials, design tool archetypes not tools, support adaption using typical household materials.

There are many different types of action within communities.

Decisions are described by gardeners as being 'ad hoc' in the contextual, workshop and prototype studies; there is continuous 'ad hoc' decision making, but we also found in the final study that there are rarer design-type activities.

There was lots of variance in practice, goals, and structure across each of the communities that we investigated, and even within the attitudes and beliefs of individual community members. This was all within a fairly constrained geographical area, with the same temperate climate and high level of urbanisation.

Community gardeners are not a homogenous group - different community members have very different interests. For instance, one participant from the Forest Garden is currently interested in mycelium and fungus, and so is leading activities involving these organisms. Some community members are interested in bees, some in the art of composting; the Glasshouses has a volunteer who is good at plumbing, leading to sink repairs. The most sustainable technological interventions may be ones where community members who are most enthused by technology (or the benefits of it) gain the skills to implement and maintain a system; not every community member needs or wants to engage with every aspect of the site.

This differential engagement has been observed in environmental sensors in other shared spaces - for example, Costanza et al. (2016) report a study where temperature sensors and displays were deployed into a number of libraries; they found that members of the public were much less engaged with the displays than staff members, even when the displays were in public areas, and at one site the majority of interaction with the display was attributed to one highly engaged member of staff.

In the provocative prototype study, we posited that providing community champions (such as the site leaders in that study) with tools that use overview representations or augment existing ones to help them to *create* or otherwise author and edit situated representations may lead to more effective action (such as better planting decisions) emerging in the space than presenting the data directly in the space. As such, we could use our understanding of shared space developed in the second primary contribution (below) to support these different types of action by different people at different times.

Design principle: Support different types of action, and support subcommunities. You do not have to design something for the whole community to use in the same way.

8.1.2 Designing for adoption in the garden

This is somewhat speculative, but taken together the findings suggest that a potentially powerful approach to designing systems that gardeners will adopt and adapt, is to design *activities* and/or *kits* rather than finished products; something that involves active engagement and learning and enhances *being in the garden* rather than a polished product that disrupts being in the garden.

This approach could support the materials re-use and tool adaption practices of gardeners, and the teaching/learning focus. Rather than designing a *thing*, we could design a *skill* that gardeners could adapt and disseminate in the way they disseminate other aspects of their practice, such as grafting clones and proper stone-fruit pruning. Those who seek to learn the skill and adopt the kits would likely self-select as 'champions' of that particular tech or skill, potentially leading to greater adoption than a product targeted at all members of the community.

Rogers (2011) argues that designers and researchers have, in the last decade, gained access to 'a cornucopia of affordable "plug and play" tools and technologies' for prototyping artefacts. This allows designers and researchers to envisage and create innovative technologies 'with a bit of wizardry and bricolage' (*ibid*). The low cost and low barrier to entry to use of these materials means they could be used directly by community growing groups. It has been argued that not only does the rise of this kind of citizen-available fabrication empower people to create their own technology, but that this self creation is *necessary* for 'smart' systems to be useful and sustainable (Diez and Posada, 2013). There is a strong culture of bricolage and materials appropriation in the communities we studied - this kind of 'tool bricolage' would be a good fit for their existing practice. After observing a number of urban agriculture sites, it is clear that bricolage is **not** completely unstructured - growers make use of sets of common materials to form tool archetypes, the properties of which are communicated as craft knowledge. This kind of *scaffolded bricolage* appears to encourage creativity and ownership by constraining the design space, and providing useful prototypical examples and use cases. Growers are then comfortable adapting novel materials that they know fit useful characteristics, or adapting solutions to the specific needs of the growing space. (Ngai et al., 2009) argue that creating kits that abstract away some of the low-level hardware challenges can help education and creativity; they found that it's not just the electronics skills and domain knowledge that present obstacles to learning and creativity, but also fragility of the materials and a lack of 'debugability'. Such a toolkit can be imagined for sensing and data in the garden, however it is important to note that these toolkits typically do not stand alone. A vital part of scaffolding that such a toolkit provides comes not only from the constraints it imposes and technical gaps it bridges, but also in supporting pedagogical materials; this is particularly the case for technology which may be completely novel to the communities into which it is being introduced, who may have no idea of the possibilities, limitations and uses of such technology (DiSalvo, Lukens, et al., 2014).

8.2 Situated Action In The Wild

Over the course of the research, we used Suchman's situated action as a lens for understanding action in the garden. The second primary contribution of this thesis are observations on the effects of situated versus overview data representations on the emergence of action in shared spaces. This addresses our second research question:

8.2.1 RQ2: How can we use RITW to design technologies for shared spaces?

8.2.2 'Situatedness' and 'Overviewness', or the importance of spatial locality.

Throughout this thesis, a distinction has been made between 'situated' and 'overview' artefacts. 'Situated' data artefacts are tightly spatially bound to the area or object that they refer to - such as plant markers. ‘Overview’ artefacts are more loosely spatially bound - they retain a spatial link to the area or object they refer to, but at a remove of abstraction - like the garden maps. We first observed these different types of artefact in the contextual studies; they represented existing archetypes of data carrying tools that could be built upon, and appeared to be expressions of practice in the garden and a result of the nature of the setting. However, the workshop revealed that there was an interaction between the two levels - both designs involved physically situated and separate overview components, especially the Birdbot group. The participants also discussed using different types of data representation in different places, such as the smiley faces for ph ‘in the garden’ and more detailed information ‘on the laptop at home’. At this point, that there *were* different types had become clear, but I was still conceptualising them as simply being different expressions of the same kind of data, but shaped slightly differently by the circumstances of the gardens. The initial plan for the research had been to move to a deployment at this point, but I felt it was important to first understand the situated/overview distinction - with an eye primarily to choosing which of these representations was most effective. The process of running the experiment - not just the findings, but the forced reframing that was required in order to think about an *experiment* rather than a more ethnographic approach, led to a shift in understanding about the nature of the situated/overview artefacts; that these different types of spatial binding appeared to lead to the emergence of different *types* of action. This led to a reappraisal of the earlier findings about situated/overview artefacts, and also a shift in perception about the garden spaces themselves; previously I had been seeing the different parts of the garden and the gardeners as separate from each other, but after the experiment findings my thinking evolved to see that the ‘cognition’ was distributed over the different parts in the indivisibly ‘stretched out’ manner that Lave (1991) discussed - whereas previously I had been conceptualising the distribution as being across separate entities[1].

[1]Interestingly, I didn’t realise that I still had this perception - I believed I was thinking about the world in terms of situated, distributed action, but actually hadn’t fully

The provocative prototype confirmed that this situated/overview difference wasn't an artefact of the experiment, but really did seem to be the case in the wild - the situated data seemed to lead to an integration of local knowledge and practice, the overview data to a more abstract 'designerly' mode of thought. Moreover, using these different types of representation led to participants discussing behaviours which were not observed in the contextual research, or discussed in the workshop - namely, rare but impactful activities and events which had a larger effect on the garden than the everyday 'ad-hoc' decision making reported by the gardeners.

According to situated action (Suchman, 2007), both of these types of artefact are 'situated' - indeed, even totally spatially remote resources are part of situated action. Thus, a better term for this situated-overview spectrum might be be *locality*. There is potentially a spectrum of locality with both situated (strongly local) and overview (more weakly local) data both being towards the local end (see Figure 8.1).

Defining Locality

We define Locality of data as the *degree of spatial binding* of that data; The most strongly local data is data which is bound directly to its related point in space. Data with the least locality is completely abstracted from its spatial context. It's the perceived mapping that's important - a row in a spreadsheet could contain very precise and accurate 3d coordinates, but this would be considered to have low locality as the representation is difficult for humans to map onto space directly. More local data leads to experimentation and integration into practice whereas less local data leads to more abstract reasoning *about* the space.

In the case of strongly local data artefacts (such as the 'situated' data artefacts throughout this thesis), the interface could be seen as the whole space; physically moving through the space allows interrogation of the local data and leveraging understanding of the physical space (Henrysson,

stopped thinking in terms of humans as silos of cognition.

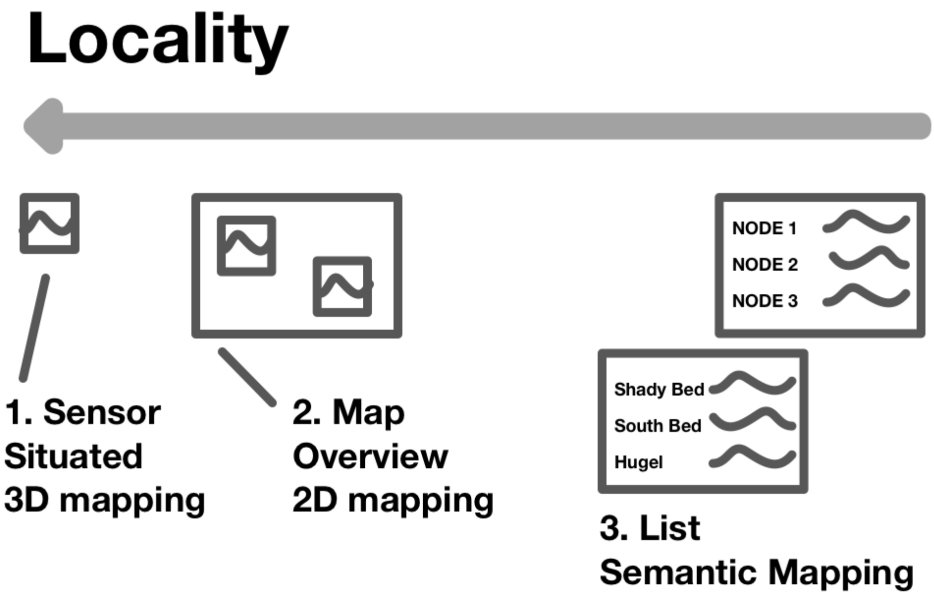

Figure 8.1: Locality

Billinghurst, and Ollila, 2005) and combining the visual modality of the data with body movements within the space, providing a richer sensory input and altering perception of the data (Hogan and Hornecker, 2016)

For weakly local 'overview' data (such as a map representation), the user is interpreting the data at a remove of abstraction rather than interrogating the data directly in real space, but the map still retains a spatial framing - the position of data items on the display is determined by their actual positions.

Data with semantic as opposed to direct 3D or 2D binding retains some degree of locality (Figure 8.2); either through explicitly spatial labels (such as 'North Bed') or by invoking existing spatial understandings (ie, knowing the 'Showcase Bed' is to the south of the garden), but exist at an even greater remove of abstraction than the maps.

Representations with this degree of locality may permit focus on the data and provide the ability to directly compare it, and also to use the spatial characteristics of the abstract space for sense making (Andrews, Endert, and North, 2010), since they are not overloading real world spatial relationships. This kind of representation could even reveal where there are interesting patterns of results which are geographically surprisingly or meaningful - such as the different sides of the hugelkultur.

Data with no spatial binding abstracts data from space completely (Figure 8.3). Its possible that this kind of representation would lead to the emergence of the most *analytic* behaviour, but also is completely divorced from the context of the space that would allow action to be taken.

Why is Locality useful?

Situated action has been criticised for describing one-off situations in great detail but not providing tools for interpretation and lacking the ability to apply findings about action in one context to predict action in another (Nardi, 1996; Kaptelinin and Nardi, 2006). Locality offers one means of interpreting situated action in shared environments; artefacts can be

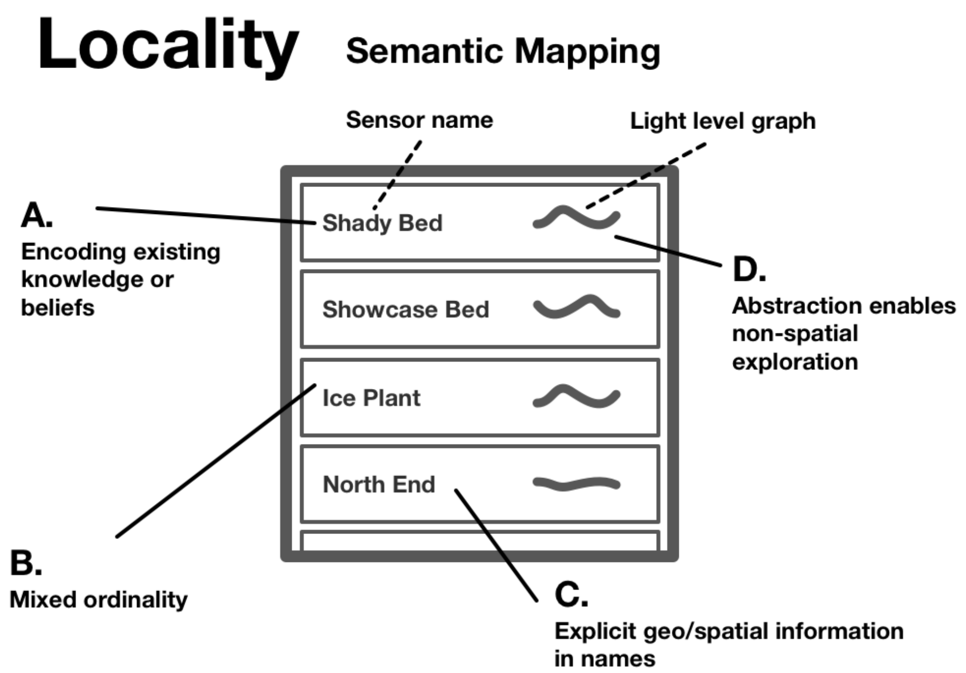

Figure 8.2: A representation with only *semantic* locality. A: Existing spatial knowledge or beliefs about the space can be encoded B: There may be mixed ordinality - the Ice Plant might be within one of the beds C: Names might encode explicit directional information

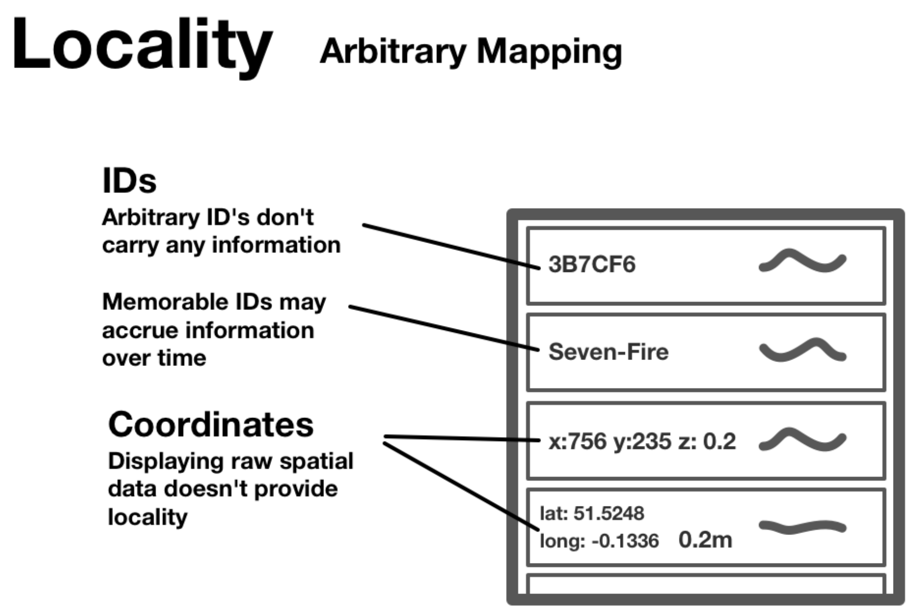

Figure 8.3: Representation with no locality. Note that including spatial information in a manner that isn't easily digestible does not impart locality. In fact, meaningless but memorable names might provide more *potential* locality since they could be associated with a location over time.

analysed for their degree of spatial binding, and inferences can be drawn about the nature of action associated with these artefacts. Additionally, locality can be used to shape the emergence of action in shared spaces; (Bidwell and Browning, 2010) argue that it is the compelling, abstract alternate reality spaces that technology creates which disrupts experience of nature. (Robinson, Marsden, and M. Jones, 2014) present this as an almost existential threat, drawing an explicit comparison between smart devices and the myth of Narcissus (Ovid, 2014). Can we instead take advantage of this disruption, and manipulate the level of abstraction via the locality of the representation to induce different types of behaviour? e.g 'understanding' vs 'planning' behaviour seen in the experiment and prototype study?

There are some unresolved questions with regards to this idea of 'locality'. For instance, an 'overview' interface if it was *somewhere else* - ie, a gardener is looking at a map of the garden, while in their house? The degree of spatial binding is the same, but the physical (and contextual) distance has increased. It is possible that there is another dimension, that we might be able to think of as *coherence* and *diffuseness*; we're only considering *coherent* artefacts here, but especially with more remote resources they may be more diffuse or distributed.

Additionally, how should we consider zooming and scale - is a larger scale (zoomed out) representation less tightly spatially bound than the same map at a smaller scale? Is the very ability to zoom into and out of a representation an element of nonlocality (since we can't effectively alter zoom levels in a physical space[2]?). There are even more cases where this locality distinction becomes difficult to apply in fully virtual environments where constraints on the apparent physical space are not necessarily the same as in a real shared space.

The degree of spatial binding (or *locality*) may not map directly onto proximity - for instance, consider a system where moving close to a par-

[2]Although a similar effect of decoupling movement from 'zoom' might be achieved with optics such as binoculars or very particular vantage points.

ticular sensor or point of interest switched an interface on a mobile device from an 'overview' representation to a more strongly local 'situated' representation. Would this lead to similar effects on behaviour as those seen in the Experiment chapter? Or is the more direct mapping to a point or object in space important?

This is similar to the AR vs Non-AR distinction we drew in the Literature Review chapter - in the case of Pokemon Go, relaxing the spatial binding to 2D position reportedly makes the game more playable, since it once the initial surprise and enjoyment observed in AR interfaces(for instance, in Javornik et al. (2016)) wears off, the tighter spatial binding actually has *negative* utility. If a 'non-AR' local representation has similar effects to an AR one, it may similarly be more useful.

Much more research needs to be done to ascertain wether locality works in the same way in different shared spaces - the research in this thesis suggests that more tightly bound data leads to experimentation and integration into practice (in some ways, a 'classic' emergence of situated action), whereas less tightly bound data leads to more abstract reasoning *about* the space; a kind of meta-action which might result in shaping the environment outside of normal practice, in a way that will lead to normal practice emerging differently, day to day.

Despite these unresolved questions, we can use this concept of *locality* as a conceptual tool to categorise data carrying artefacts, and in order to design systems for shared spaces - even if the *way* locality works is not generalisable to other contexts, its use as a *conceptual tool* may well be transferable.

In addition to the findings that emerged by performing the research about shared spaces in general, and about the garden in specific, we gained insights into the use of the RITW framework.

8.3 Using the RITW framework

We selected the RITW framework for this research since the shared, unstructured environment and tensions around technology use and non-use appeared particularly amenable to a RITW approach. There are many frameworks in HCI; they are often presented as the *outcome* of research, offering a means of conceptualising and communicating research approaches and findings, and providing the reader with conceptual tools to think about the problem space. Such frameworks are frequently criticised however for lacking concrete application to future research (Furniss et al., 2015). Attempting to *use* a descriptive framework (in this case RITW) to structure a course of research is one way to adapt and extend them as formative tools.

Based on the findings from the research we propose a way of extending the RITW framework intended to help researchers when making choices about which technology, method and approach to use when applying a RITW approach, addressing our first research question:

RQ1: How can we select and design technologies for RITW?

In this section, we will discuss three proposed extensions, their rationale and their concrete application:

1. RITW can be seen as an iterative process of constraining the design space for a final deployment
2. The connections between 'core bases' in the framework can be used to guide research
3. Methods for designing deployments focusing on *provocativeness* as an axis

8.3.1 Extension 1: RITW is an iterative process of constraining the design space for a final deployment

The RITW framework consists of four inter-related ‘core bases’: Theory, In-Situ, Design and Technology (see Figure 8.5). These bases allow the ‘scoping and operationalisation’ of the project. This is useful for characterising projects from a ‘top down’ perspective, such as at the end of a project or during planning, however although the inherent interconnectedness of the model represents the interdependent nature of influences in RITW, the lack of an ordering or natural endpoints does make it difficult to know where to begin a project. It is possible to extend frameworks at this conceptual, broadly scoped level – for example, Harper et al. (2008) added an ‘understanding’ phase to the traditional User Centred Design model. However, rather than this kind of structural extension (ie, the addition of another core base), we elaborate on the methods that can be adopted *within* the framework at a more granular level.

Although Research In The Wild often focuses on a single ‘final deployment’, in practice RITW processes involve more than just this ‘final deployment’. Indeed, it could be argued that one way to constrain the design space is to explicitly approach RITW not as a single deployment, but as an iterative research process that *includes* this kind of ‘grand deployment’. As we progressed through different research activities, it became apparent that despite the interconnected nature of the RITW framework the focus of the researcher is on different core bases at different times. Researchers ‘move around’ the framework from base to base, building up an emerging theory and conception of the research. Each research activity acts to constrain the design space for the final deployment by contributing to the researcher’s emerging conceptionFigure 8.4.

Framing the RITW framework as an iterative process of constraining the design space for a final deployment in this manner has two benefits: firstly it allows us to expand the scope of activities that can fit within the RITW

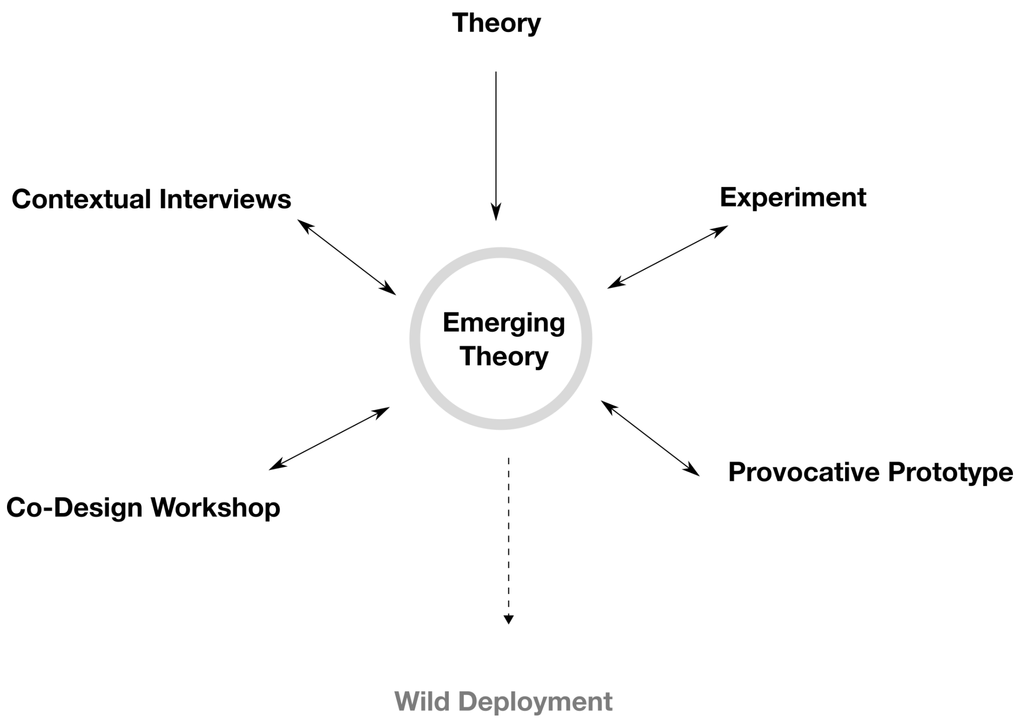

Figure 8.4: An alternative way of conceptualising the research is that each activity feeds into an emerging *conception*, ie the researcher's combined understanding of what is happening, the evolution of which drives new activities, until the researcher feels confident that a deployment can be made.

paradigm, as any activity that is helping to constrain the design space is in principle justifiable, even experiments and lab studies which have been argued to be inherently incommensurable with RITW (Kjeldskov and Skov, 2014; Rogers and Marshall, 2017). By framing studies within an iterative RITW process, we can pragmatically use experiments to help inform design decisions. In this case, we are not seeking underlying truths *per se*, but rather using each study as a way of changing the way that we as the researcher think about the design space. In the wild research inherently rejects the idea that there are "simple deterministic explanations between technology and use" (Brown, Reeves, and Sherwood, 2011), and it is this core element that is most important to the development of this method. Although experiments probe simplistic relationships, observing the manner in which they change behaviour can still help to develop the researchers overall ideas and contribute to their emerging conception; even the act of designing an experiment forces the researcher to think in different ways about the problem space - the decision of what to do next is then whatever can help with developing the researcher's conception via abduction. We can consider this a logical progression for RITW - RITW goes even further than cognition in the wild in rejecting the false objectivity of the disinterested observer, and embracing the subjectivity of the researcher in changing the behaviour of participants, not passively observing. The next step is to erode the distinction on between the effects of *method* and *findings* on the researchers' emerging conception. Lave (1988) observed that participants behaviour was changed by the act of observation, and from this project we observe that the process of researching has changed the *researcher's* behaviour. As such, we would argue that detailed reflection on methodology and design decisions is vital not (just) to allow replication or assessment of the quality of the research, but because these methodological acts have as much of an influence on the outcome as data from studies.

The second benefit is that the movement of the researcher around the bases enables the next extension which is the focus not just on the bases in the

RITW figure, but also on the *connections* between the bases. We can focus on the connections that feed in and out of the base that a researcher is currently focused on.

8.3.2 Extension 2: The connections between 'core bases' in the framework can be used to guide research

The second way we propose extending the RITW framework is to use this concept of moving between the RITW bases to explicate the interdependencies between the four core bases. Identifying a base of current interest and the connections that feed into and out of it helps the researcher to formulate the questions we need to ask to improve our understanding of the base we are currently focusing on. The concrete application of this is a way to structure RITW projects and decide on activities based on this examination of the relationship *between* the core bases.

Although the four bases can be looked at from a 'project' level, during the research the perspective of the researcher moves around the structure, and the nature of the influence of the bases changes.

As such, we can see that when we are 'standing on' the Design base, we can imagine a shift in perspective (see Figure 8.6). The refocus on the design base of the figure, and the lines connecting it gives us three connections: Technology-Design, Theory-Design and In Situ-Design (marked A, B and C in Fig. 2). The benefit of this is that we can use those connections as more constrained entry points into the RITW framework; for instance, we can use them to identify what information we need and decisions we have to take to inform *Design*. We could use connection A (Technology->Design) to make decisions about what to design - not primarily in the sense that it restricts what you can do, but in the sense that it effects the community; e.g., updateability, sustainability, level of engagement, importance of appropriation. Connection B: (Theory->Design) can be thought of in part of how it shapes the goals of the research and in part as it applies to the intervention, depending on what stage of the research process you are at.

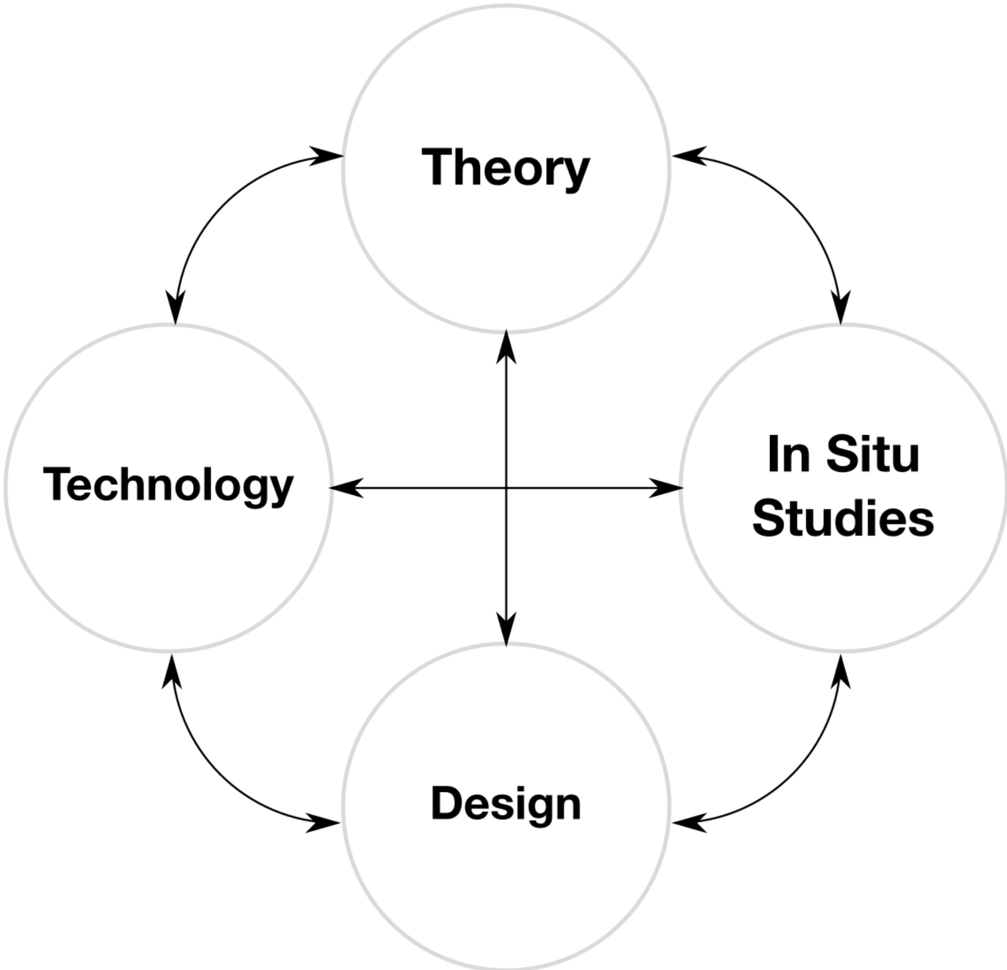

Figure 8.5: RITW framework from Rogers and Marshall (2017). Adapted from figure on p.6.

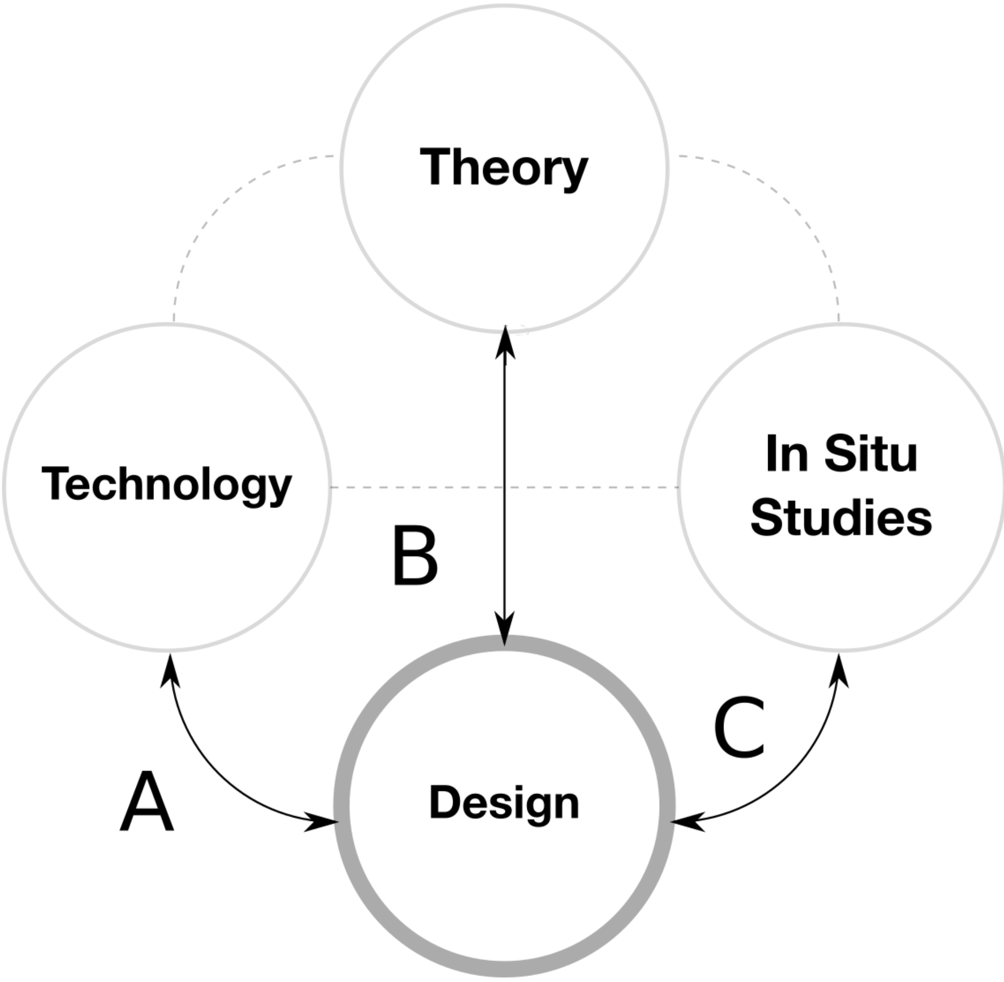

Figure 8.6: RITW framework focusing on the Design connections

For example, the design of the entire process could be led by a particular theory as in Yuill and Martin (2016), or it could be applied very specifically to the design of a specific prototype. Connection C: (in-situ->design)The In-Situ inputs here are contextual information from previous studies, and what is known about the community. In this sense, the In-Situ base is broader than studies alone, covering ‘context’ more generally. Based on these three connections A, B and C, we could identify that as our next steps we need to decide *what technology to use*, *what theory to use* and *what studies to do*.

This method of focusing on connections is a tool for focusing within the RITW framework on a particular base of interest - it can be used whenever a researcher is ‘on’ a particular base, to help decide what to do next, but the connections can also be used to think about other aspects of the relationship between the bases; For example, looked at another way these three connections let us consider 3 motivations for a RITW project:

A. Fixing something in the world (In Situ focus) B. Using something in the world to explore theory (Theory focus) C. Introduce novel tech to see what happens (Technology focus)

Thinking about these can help to frame the current research or to evaluate tradeoffs - these motivations are not necessarily orthogonal, for example, ‘community-led’ concerns and ‘designer-led’ aspirations, and the tension between augmenting current practice and finding out something new.

We can use these connections to think about any of the bases (alone or in combination), at any point in the process of a RITW project; this can help the researcher to concretise and operationalise various aspects of the research. Here, we applied it to our RQ3 - how do we select and design technologies for a RITW deployment?

8.3.3 Extension 3: Questions to ask when designing deployments

The third and final extension of the framework is to derive a set of concrete questions and decision points that can be used to constrain the design space for prototypes and final deployments.

The extended RITW framework uses the 4 bases to iteratively constrain the design space, but at some point you actually have to operationalise the design of a deployment. Potentially, this needs to be done multiple times, as probes and prototypes are not necessarily the 'final deploy'. How can we approach this? As discussed in the Introduction chapter, although the design of this deployment is a 'central concern' in RITW projects (Rogers and Marshall, 2017), the exact nature and design of the technology to be deployed can be difficult to specify. Based on the connections to the 'Design' base that we identified in the previous section and the reflections from the Prototype Study chapter, we propose some simple questions and decisions that can help guide the process.

Core Questions

In order to approach the design of a RITW deployment, we suggest asking 2 *core questions* which will inform 4 *key decisions*.

The core questions are:

(i) What do you want to understand and achieve? This is slightly different from, although probably related to, the research question - it is about what you want the *prototype* to achieve, not what the *research overall* wants to achieve. In some ways, this is a similar distinction to the one between research questions and interview questions - you use the latter to address the former. The answer to this question can be used as a design challenge, as in the Provocative Prototype chapter. Are you solving a community problem, or finding something out? What mix of the three motivations we identified in the previous section are most important? In the previous chapter, we ended up with "*We want to elicit responses to possible future garden tech that shows environmental conditions, with a focus on probing the different effects of situated and overview data on community practice - without disrupting practice of community members who do not want to engage with the prototype*", which we used as the basis for the design challenge.

(ii) How provocative should the prototype be? This was a question that dominated many decisions in the provocative prototype study (indeed, the decision to use a 'provocative' prototype is the defining characteristic of that study!). Using *provocativeness* as a dimension for helping to operationalise the design of the deployment was extremely helpful in informing different aspects of the design (for example, the AR modality was provocative through its novelty and 'techiness', but the graphs themselves were a very familiar representation for the users).

Tuning different aspects of provocation was challenging - we found that there were many different dimensions of provocativeness and it can be a difficult concept to operationalise and balance. (Boer and Donovan, 2012); argue that the balance between inconspicuousness and intrusion is vital - if the prototype is not intrusive enough it won't elicit interesting data, but if its *too* intrusive to practice it will be rejected and not engaged with. However, actually *achieving* this balance is problematic - Bardzell et al. (2012) argue that this is particularly challenging for researchers since we may lack design training, and there is a paucity of heuristics for provocative design that researchers can draw on in the absence of professional design skills. One approach[3] which maps well onto our experience from this thesis, and provides some scaffolding for thinking about provocation in design, is the use of the dimensions of Conceptual, Functional and Aesthetic provocation (Raptis et al., 2017). Boer and Donovan (2012)'s 'Guidelines for provotypes' may also useful in addressing this question of *provocativeness*.

[3] An alternative approach might be to add a professional designer to the research team, as in (Rogers, W. R. Hazlewood, et al., 2010).

A distinction should be drawn here between intermediary and final deployments; the goal of this *specific* deployment isn't necessarily the end goal. And indeed, the final deployment doesn't necessarily have to be a production system that will last a long time (although it could be!). As with the difference between research questions and what the prototype should achieve, the scope the question of provocation to what you want to achieve *at this stage in the process.*

The important thing is to consider each aspect of the design in terms of how it will provoke, and how this provocation will help answer the understanding/achievement question, and to reflect on it while making design decisions. Different aspects of the system can have different tradeoffs, especially for systems that are distributed across a space; different levels of provocation may be appropriate for different elements.

Key Decisions

Following this, we suggest explicating the following four decisions, informed by the answers to the core questions:

1. Selection of technology - By which we mean, which broad paradigm or paradigms? What things to use and how? For instance, a technology might have high familiarity, but may not be context appropriate; or it might have high appropriateness, but not provoke interesting behavioural changes and responses. In this thesis, common industrial and commercial technologies were identified, and used as a basis for technology candidates, and the final selection was shaped by a synthesis of the existing data representations and context sensitivity from the first study, along with the findings from the design workshop that gardeners were open to more novel tech that expected after the first study, especially sensors.
2. Modality and representation - How is the deployed system represented to people? This applies from high-level choice of modality, all the way to specific interface details. For instance, tangibles might be

minimally invasive and good for gently augmenting a particular community practice, but not help a researcher understand how access to a completely novel data source would impact the community. In the provocative prototype study, we considered a range of visualisations that had different characteristics before settling on the line graphs to best support our understanding goal and provocativeness balance.

3. Spatial and temporal scope - How long should the deployment be? And where should all the parts go? Is it important to remain embedded in the community after the research? Boer and Donovan (2012) talk about provocation on encounter, on use and on reflection; the temporal scope will affect the choice of level of provocation at each point, and equally the decision to focus on a particular type of provocation could inform the temporal scope.

4. Fidelity of Prototypes - Which parts of the prototype really need to work, with what kind of depth, and how should it look and feel? A central question is whether a professionally designed prototype is needed or is it better to use a low tech one? Should it look like a real product, but be non-functional? We saw in the Workshop study that the tea box enclosures led to positive reactions - would the results of the workshop have been different if the sensor and output boxes looked more like products? (Raptis et al., 2017); argue that researchers often treat well-finished product-like design as a normative good in *in the wild* research, without considering the assumptions underlying wether this is actually appropriate.

The outputs from these 2 core questions and 4 key decisions represent a set of practical constraints for informing the prototype design, developed from our experience of applying RITW.

8.3.4 Summary

In this section on extending the RITW framework, we moved from a conceptual to a practical scope, using reflections on the process of using RITW as a guide to research. We discussed three extensions:

- Extension 1: RITW is an iterative process of constraining the design space for a final deployment
- Extension 2: The connections between 'core bases' in the framework can be used to guide research
- Extension 3: Questions to ask when designing deployments

Each extension enabled and led to the development of the next, however in practice a researcher can use any or all of them as desired; 'higher level' extensions are not required to use 'lower level' ones. For instance, a researcher could use extension 3 as a practical guide to developing prototypes for an intervention, without having to adopt extensions 1 or 2. These extensions are neither authoritative nor exhaustive; there are potentially many other extensions and adaptions of the RITW framework that may be complementary, orthogonal or even contradictory to the extensions presented here.

8.4 Limitations and Future Work

We have suggested a set of extensions to the RITW framework that can be used to perform practical RITW research, arising out of a specific research project. This is very much driven by research goals and in service to a phd thesis; would these framework extensions be applicable to more 'typical' RITW projects, which often include more team members in collaboration, and which may be driven more by external requests? Also, how much of the output is driven by the specific domain? For instance, is the apparent importance of 'provocativeness' of general use in RITW, or is it something that's only important in community gardens? The tension between what Ehn (1989) calls 'tradition and transcendence' was at the heart of why this particular problem space was an interesting application are for RITW, so to some degree the provocativeness element may have been entailed by the choice of research domain.

Since this thesis builds on the RITW framework, the *output* comprises extensions to that framework - future research could focus on the application of these extensions, evaluating and modifying the extended framework and examining if concepts of provocativeness are equally useful. Either by using and evaluating the extended framework in its entirety, or by more focused investigations; for instance, a study could use the second extension to develop pragmatic tools for different aspect of decision making within RITW, and attempt to apply it to a specific deployment. Or the use of extension three could be evaluated in the development of a prototype for deployment.

Further research is also needed on how RITW projects are undertaken, both using the RITW framework and more generally; what is current research practice around RITW, and what areas are useful for researchers? Which areas could be supported using methodological or technological tools? A meta-analysis of the literature could be one avenue to investigate existing practice, and would provide a good overview of the current state of the art; however to some degree it would only show how people are using RITW in their *reportage* for publication. Shadowing research teams involved in RITW may offer the opportunity to capture more actual behaviour and practice, although at a cost to scale and generalisability. One benefit that observing research teams in this way would have over this current thesis, is that there would be a clearer distinction between the research the team is engaging in, and this meta-research on their practice; the two things are impossible to unpick in the current research. For instance, the researcher engaged in reflection on the methodology at each stage of the research, in order to address Research Question 1 - however it's possible that this reflection on method is *in itself* a valuable part of RITW practice.

Another area that would be interesting to pursue in terms of evaluating the extensions, is the applicability of RITW and the extensions to RITW to practice outside of academia. RITW offers the ability to go beyond typical UCD approaches and enable potentially more innovative design, however the scope and timescales are such that large RITW projects appear difficult to adapt to an industry setting. The RITW framework provides a good starting point for adaption to these kinds of settings, especially if extensions can be developed to support the design of rapid, lightweight probes and studies.

A major limitation of the research is that we only deployed a small number of prototypes in a single environment. Additionally, although the sensing aspects of the system were deployed over a longer term, probing with the interface prototypes was momentary. Whilst this worked well for eliciting responses to the novel technology and concepts, it does not tell us about long term adoption and usage of such systems. As such, an ideal next step for future work would be a full blown, longitudinal deployment in the wild with multiple sites. This would allow the investigation of adoption and adaption over time, and probing into low frequency but high impact activities (such as large scale clearance, construction of new beds and planting). Investigating the design and deployment of activities and kits into communities would also be interesting; how could we track the usage and adaption of these over time, especially as they (if they) evolve and change?

It is also impossible to say if Locality is more broadly applicable outside shared spaces (or even community gardens). It is possible to argue that it may still be useful as a conceptual tool even if the nature of how locality alters action is different across domains, but we can't say without further research if it is even relevant or applicable, similarly to provocativeness. Further exploring the concept of Locality could provide a number of avenues for further research; for example, probing the effects of different levels of spatial binding in different contexts, examining the effects of Locality on non-visual modalities, modifying the Energy Harvesting Task based on different wild contexts. Varying the spatial and temporal setup of the Energy Harvesting Task would also be very interesting, for instance in larger spaces and over a longer time frame, perhaps for example set up within an office building, with patches spread out over the building and with only one turn per day. The Energy Harvesting Task is not a validated task, and was created for the specific needs of the research; although within the context of this thesis, this isn't strictly problematic (indeed, arguably having to create a task is actually a positive in terms of encouraging reflection and reframing), more research would be required to see if the task itself leads to stable results, and across what circumstances, in order to asses its value for further research. Indeed, there are potential other interpretations of the results seen in the experiment (which are discussed in the limitations in Chapter 6) - more research is needed to confirm if the difference in behaviour over time that we observed is being manipulated by the situated/overview data representation, rather than some idiosyncrasy of the task or study design.

Although a broad sampling of communities was made, this thesis is product of a very specific location, culture and climate; even more so than a typical research project, differences in growing conditions means the specific domain findings may not be applicable to community gardens outside of London. However, the flexibility of the RITW framework means that even if the research is not *generalisable* to other contexts, it should be highly *transferable*.

One avenue for future work that could investigate the generalisability and/or transferability of the findings and methods would be to investigate other shared spaces, with some level of ability for inhabitants to make changes to the space. For instance, office HVAC (Heating, Ventilation And Cooling) systems could be an interesting space - would presenting environmental data (such as temperature) in a situated versus overview manner lead to different thermostat usage patterns?

Overall, there are a number of questions raised in this thesis and discussed here. The three main, overlapping, areas for further research appear to be: use and evaluation of RITW and the extended framework, the nature and use of Locality, and long term deployments into community gardens and other shared spaces.

9 Conclusion

This thesis explored community gardens as shared spaces, and the tension between the potential benefits of sensors and data in community practice (Campbell, 2013) and the rejection of these technologies by community gardeners (Hirsch, 2014; Odom, 2010). As part of the research process, we have also conducted an empirical comparison of situated vs overview representations of information, and considered the implications of this for the design of interactive technology in shared spaces, and have additionally reflected on the use of Rogers and Marshall (2017)'s RITW framework to guide research.

The first of the primary contributions is a set of design principles that can be applied to the specific domain of community gardens; these principles were developed through the synthesis of all the research activities, and taken together suggest that a potential route to technology adoption in such contexts is to design *skills* rather than *finished products*, perhaps via activities and kits that gardeners could adapt and disseminate in the way they disseminate other aspects of their practice. Possibly more importantly, this contribution provides support for the idea that it is not technology itself that is rejected, but rather the specific design of that technology (Bidwell and Browning, 2010; Goodman and Rosner, 2011). As such, despite previous indications to the contrary (Hirsch, 2014; Odom, 2010), this contribution suggests that sensors and data *are* a potentially fruitful area for investigation for HCI.

The second primary contribution of this thesis are empirical observations on the effects of 'situated' versus 'overview' data representations on the emergence of action in shared spaces. We observed 'situated' and 'overview' data in the gardens in the contextual study reported in chapter 4, and again in the designs in the workshop study presented in chapter 5. The experiment study in chapter 6 directly compared the effects of these two types of representation, demonstrating that the degree of spatial binding changes the effects that data has on behaviour. The prototype study in chapter 7 showed that similar effects applied outside of the lab in real community garden context. As such, this contribution shows that manipulating the degree of spatial binding, or 'locality', of a data representation could be a powerful tool for shaping action in shared spaces, and suggests a number of avenues for further research into the nature of 'locality' and its effects.

The reflections on the use of the RITW framework represent the secondary, methodological contribution of this thesis. Firstly, framing RITW as an iterative process where the researcher develops an emerging theory that constrains design allows the broadening of activities that can be part of a RITW project, such as the experiment in Chapter 6. Secondly, focusing on the connections in and out of the base that a researcher is currently focused on can be used as a tool for thinking about how to develop the emerging theory at any point in the RITW process. A concrete example of this is the third reflection, which was developed by focussing on the connections in and out of the *Design* base; this final reflection is a set of concrete and practical *questions* and *decisions* researchers can use to help select technologies and design directions for RITW probes and deployments. These contributions also demonstrate that there is a value in *using* frameworks to guide research - even if frameworks are supposed to be descriptive rather than prescriptive, they offer a conceptual framing for the research, helping us to think in broader terms than individual studies. More importantly, using frameworks in this way allows us to investigate how well they map onto the processes they attempt to describe, and to develop and strengthen these frameworks. Using and reflecting on a framework not only has practical benefits but also has the benefit of encouraging reflection on the methods and process of research. Suchman (2007) talks about *action* as being radically performative, with action shaping circumstance, as the circumstance shapes action in parallel. Using the lens of situated action, this applies equally to the case of *research* as it does to any activity, despite it being a highly analytical task; the researcher is changed by the research, rather than being an objective observer. By the same token, frameworks can be developed and evolved *through use* - they both help guide the research, and are modified in the process. Making this reshaping of the researcher and the research tools explicit through reflection on the use of research frameworks can help lead to the innovation of methods and findings in HCI called for by authors such as (Brown, Reeves, and Sherwood, 2011).

Ultimately, this exploratory thesis offers two main strands for further research; Firstly, we have demonstrated that sensors and data in community gardens is an area of potential interest to HCI researchers, and that 'technological rejection' is not inherent to this domain. We present design principles and possible directions for further research into systems which may be adopted and adapted by community gardeners. Secondly, we present findings that suggest *locality* of data representations in shared spaces may affect the emergence of action in these spaces. Exploring the different aspects of *locality*, and whether the effects are stable across different contexts, and if it is applicable in shared spaces more generally provides a rich vein of potential further research.

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